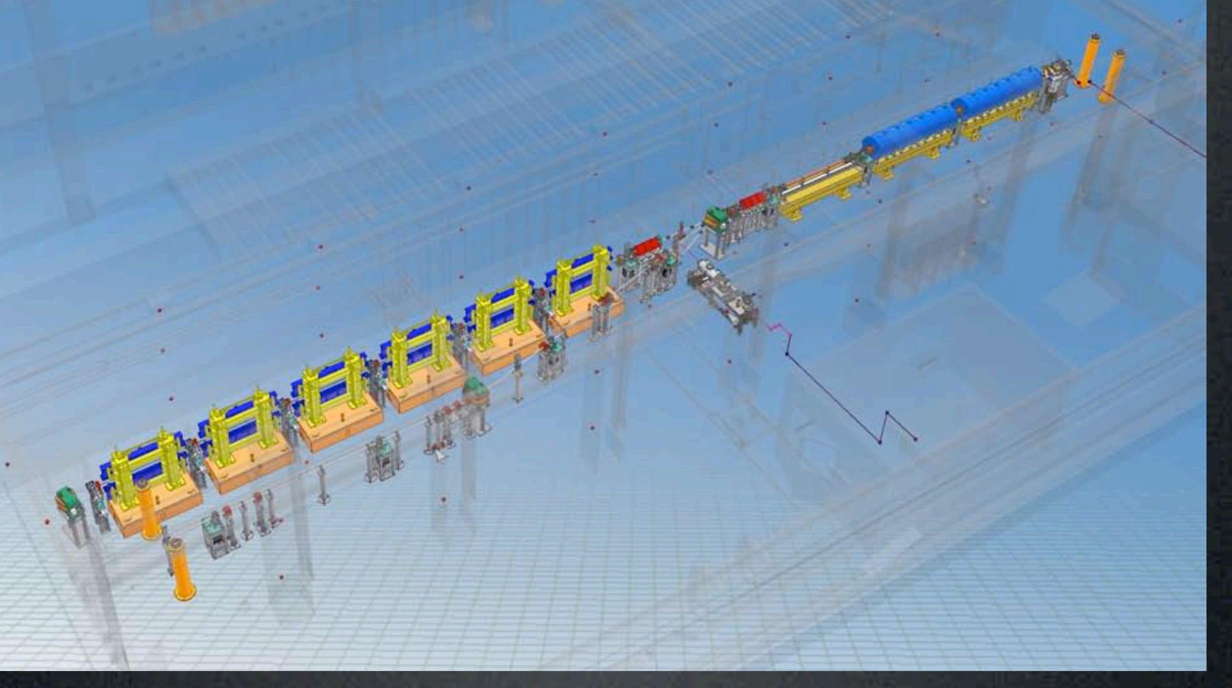
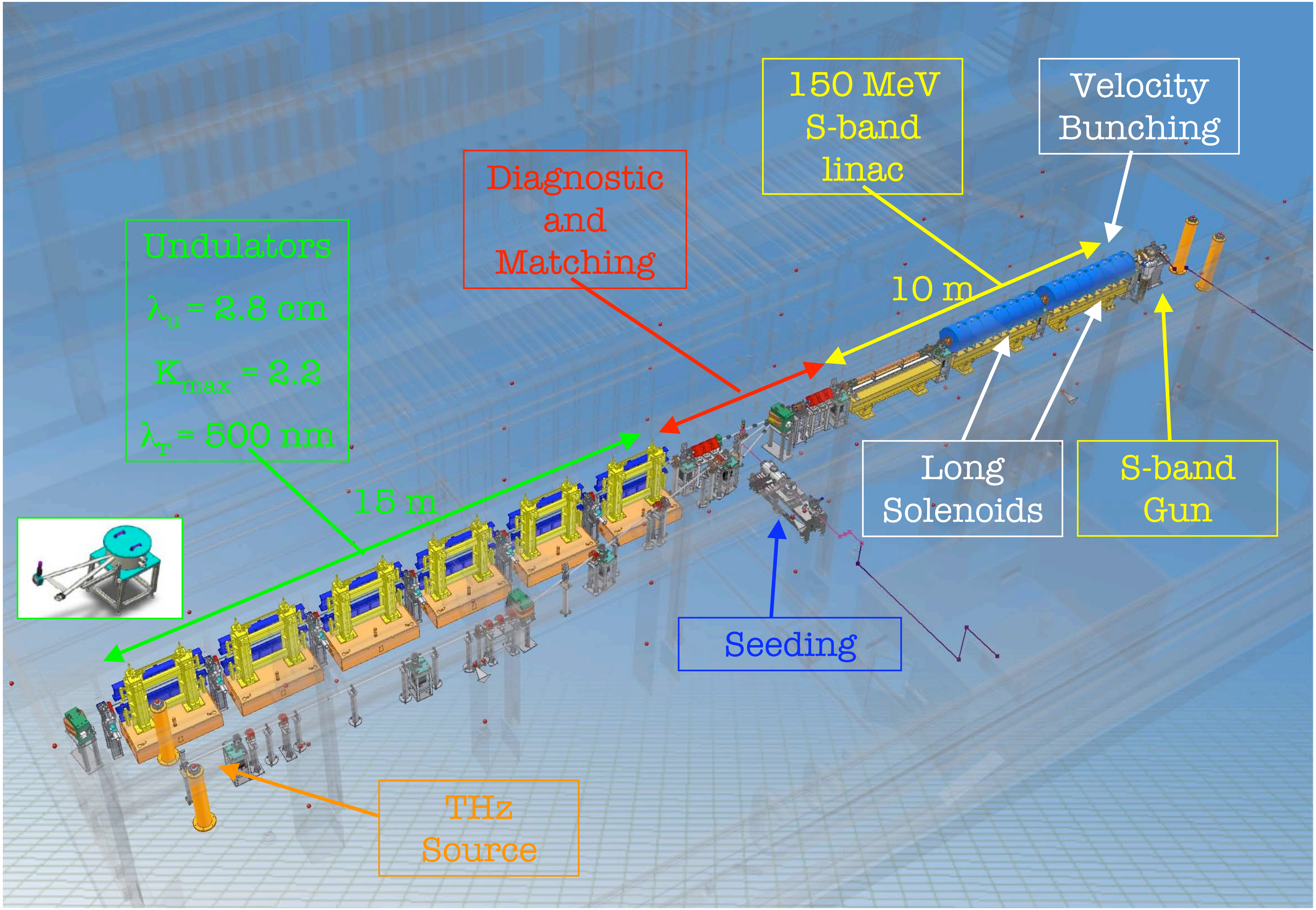
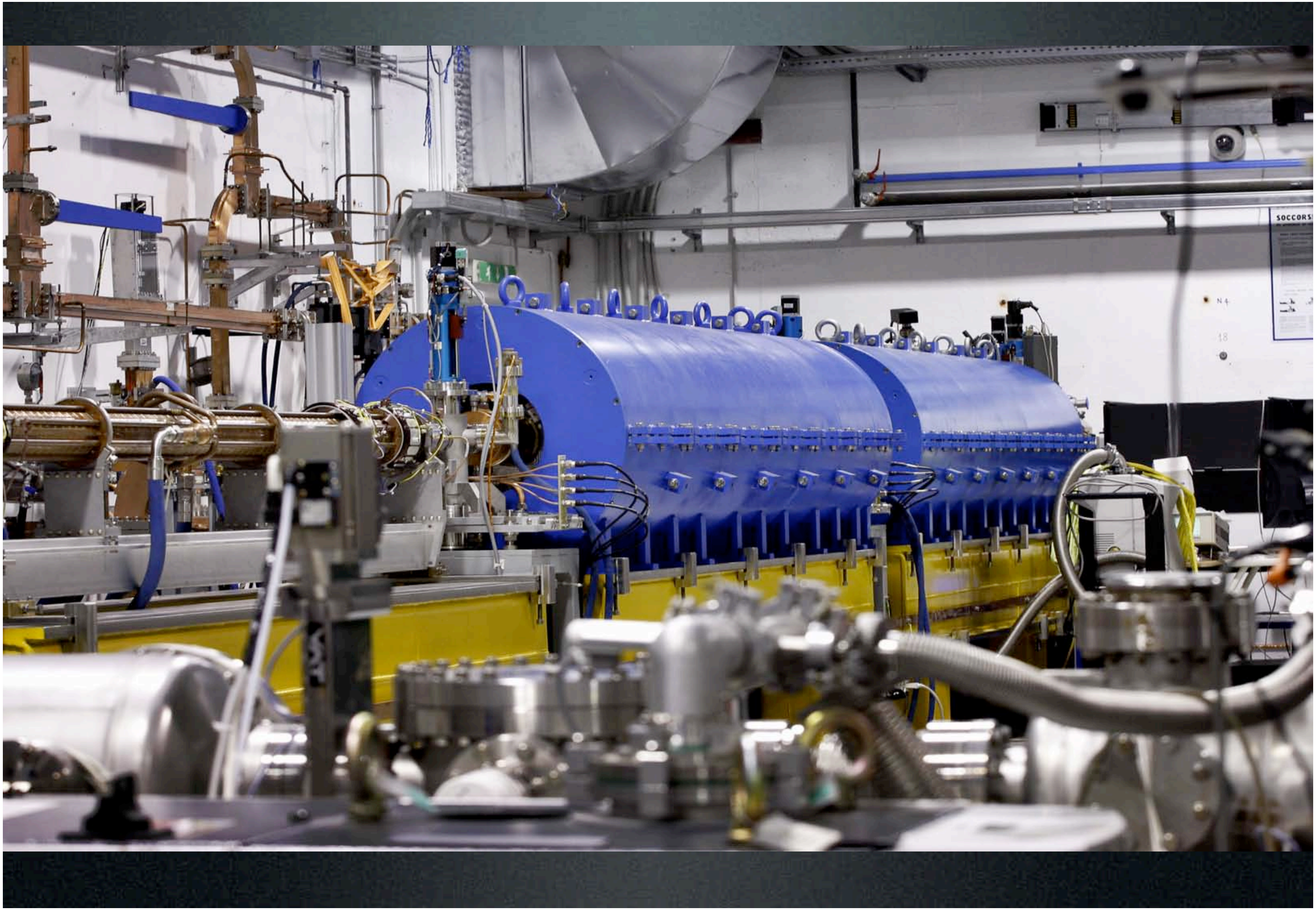
SPARC status and plans

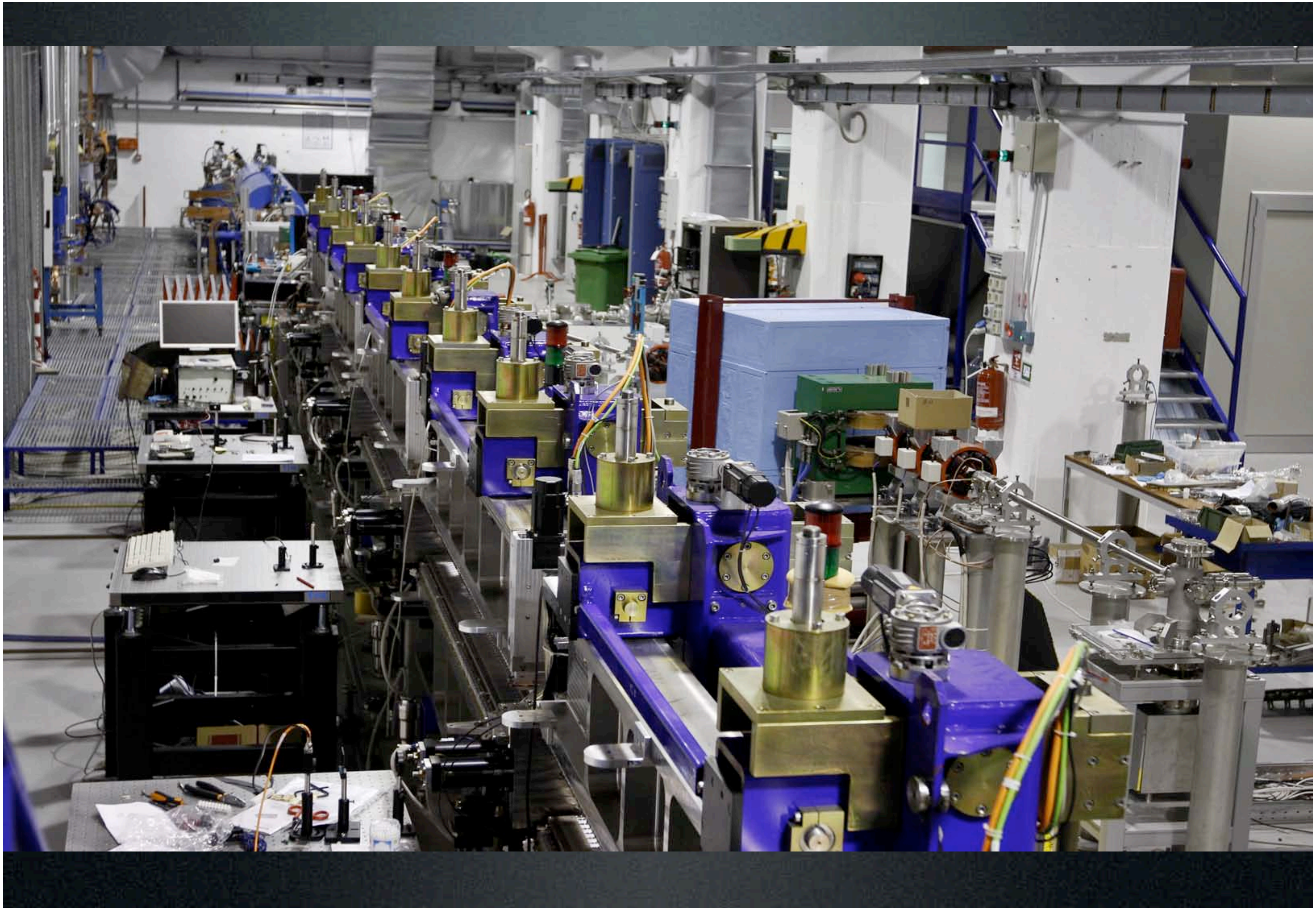
Massimo Ferrario
on behalf of the sparc team



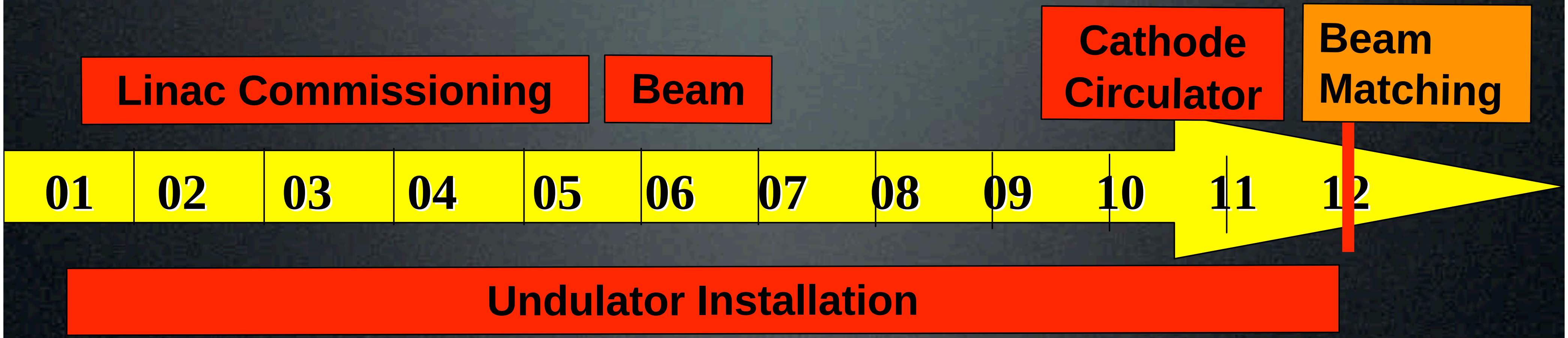
38th LNF Scientific Committee Meeting - 11 May 08


150 MeV S-band linac
Velocity Bunching
Diagnostic and Matching
Undulators
λ_u = 2.8 cm
K_{max} = 2.2
λ_r = 500 nm
10 m
15 m
Long Solenoids
S-band Gun
Seeding
THz Source



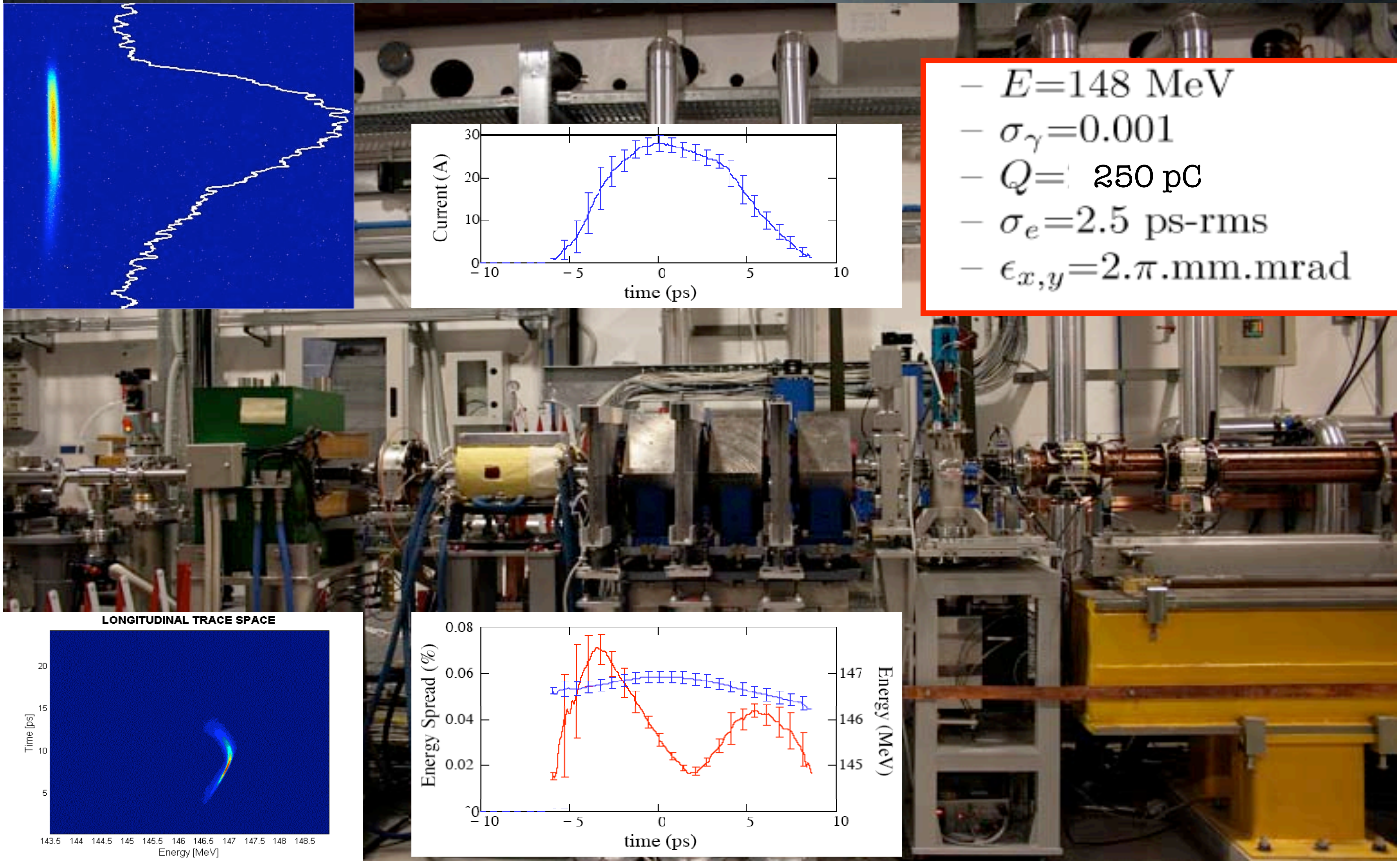


2008 activity



SASE at 500 nm

Electron beam parameters at the linac exit



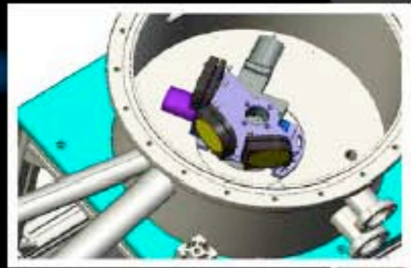
- $E=148$ MeV
- $\sigma_\gamma=0.001$
- $Q=$ 250 pC
- $\sigma_e=2.5$ ps-rms
- $\epsilon_{x,y}=2.\pi$.mm.mrad

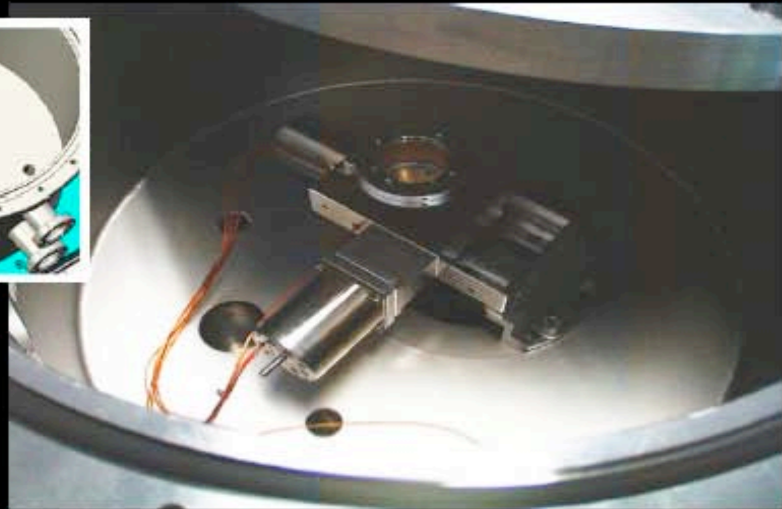
Laboratory for UV and X-ray Optical Research

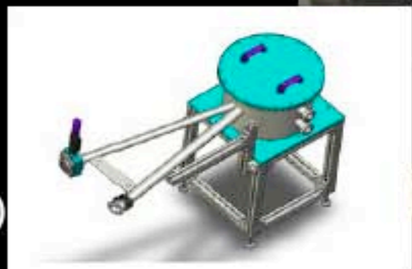
LUXOR

CNR-INFM

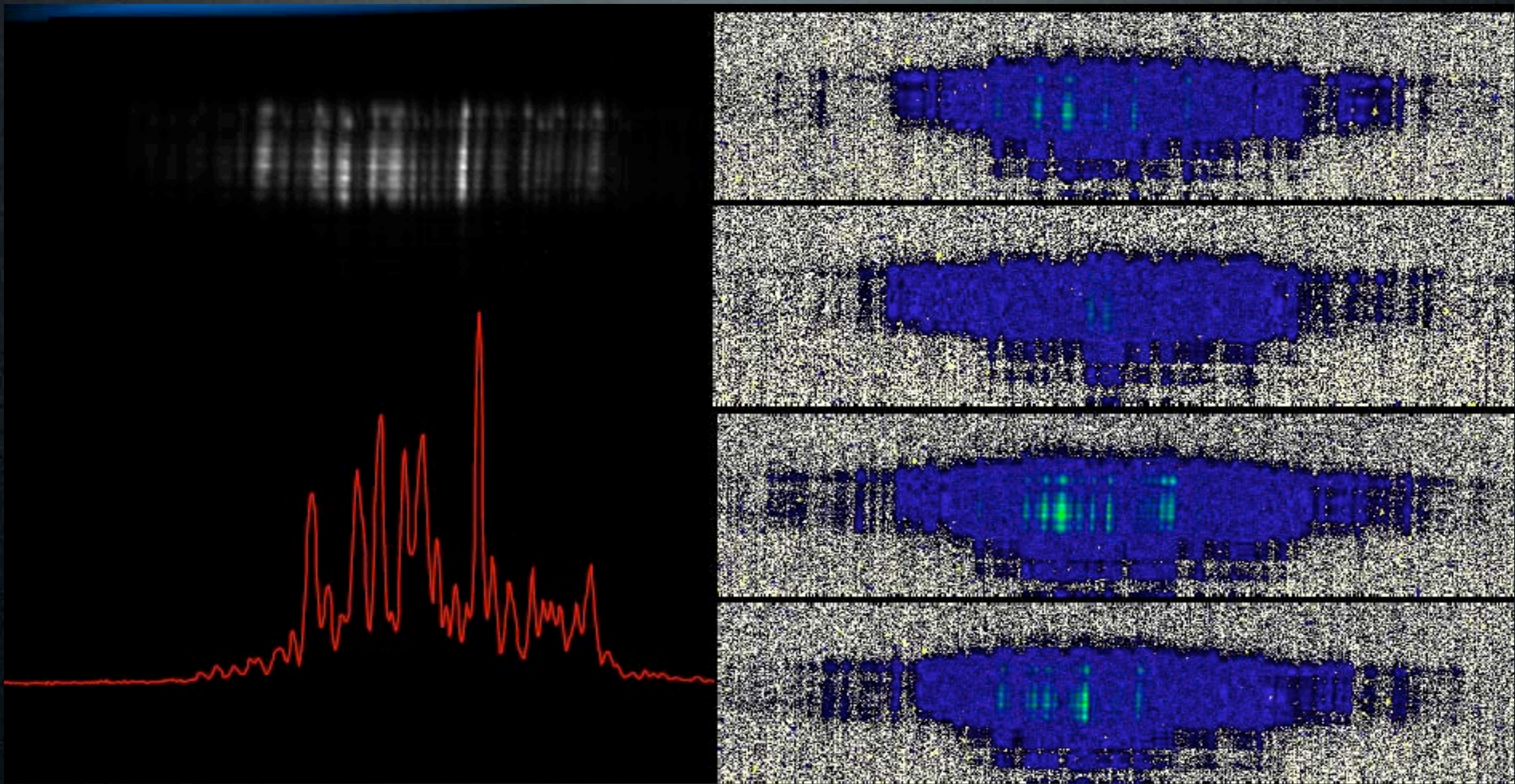
- Entrance slit:
  - minimum aperture 20 μm
  - maximum aperture 2 mm
- Entrance/exit arms: ≈1 m
- Three gratings:
  - 600 gr/mm, 150-550 nm
  - 1200 gr/mm, 100-350 nm
  - 2400 gr/mm, 50-150 nm
- Acceptance
  - 25 mrad × 25 mrad (1.4 deg × 1.4 deg)
- CCD detector (Roper Scientific)
  - Thinned and back illuminated
  - Pixel size 20 μm
  - 1340 × 1340 pixel
- Resolving element
  - 0.034 nm/pixel (600 gr/mm)
  - 0.017 nm/pixel (1200 gr/mm)
  - 0.0084 nm/pixel (2400 gr/mm)

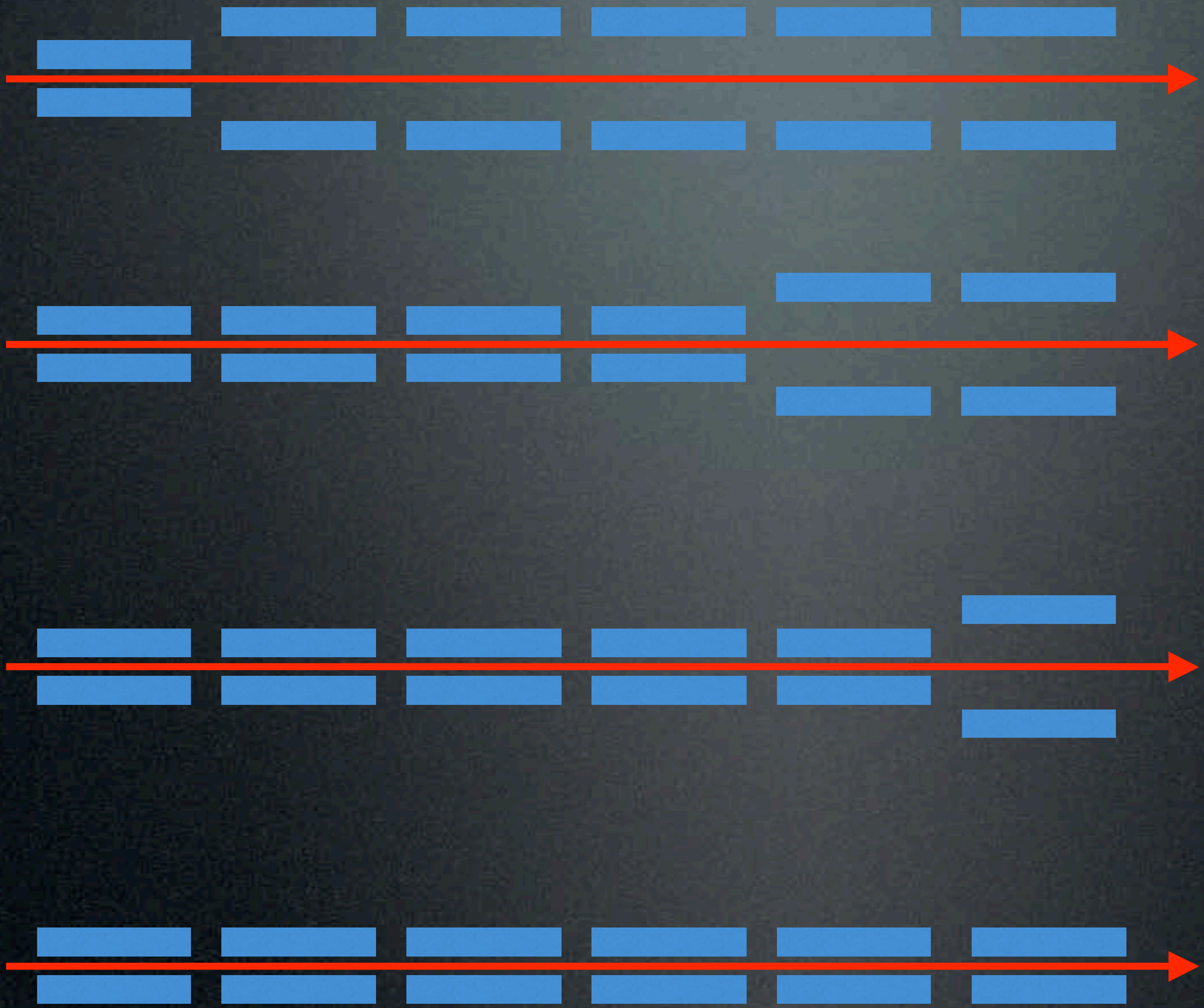


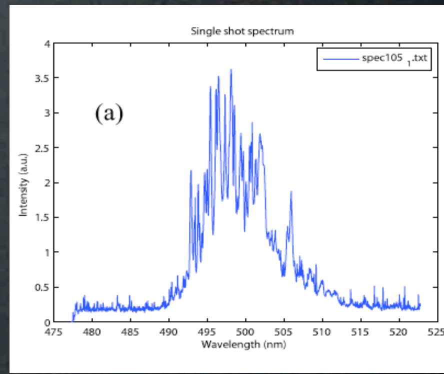


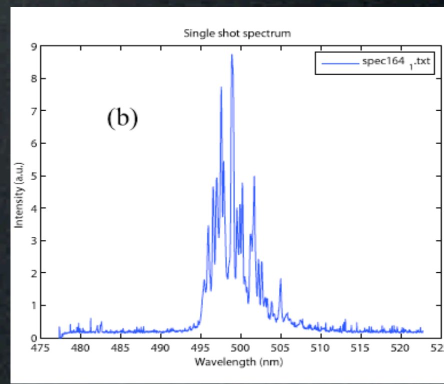


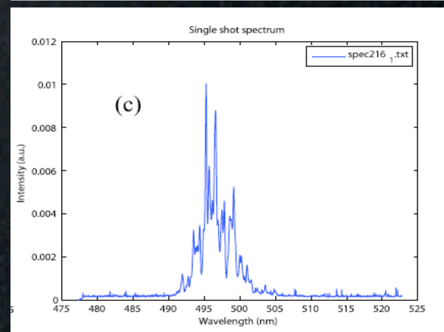
First experimental evidence of SASE on February 17th



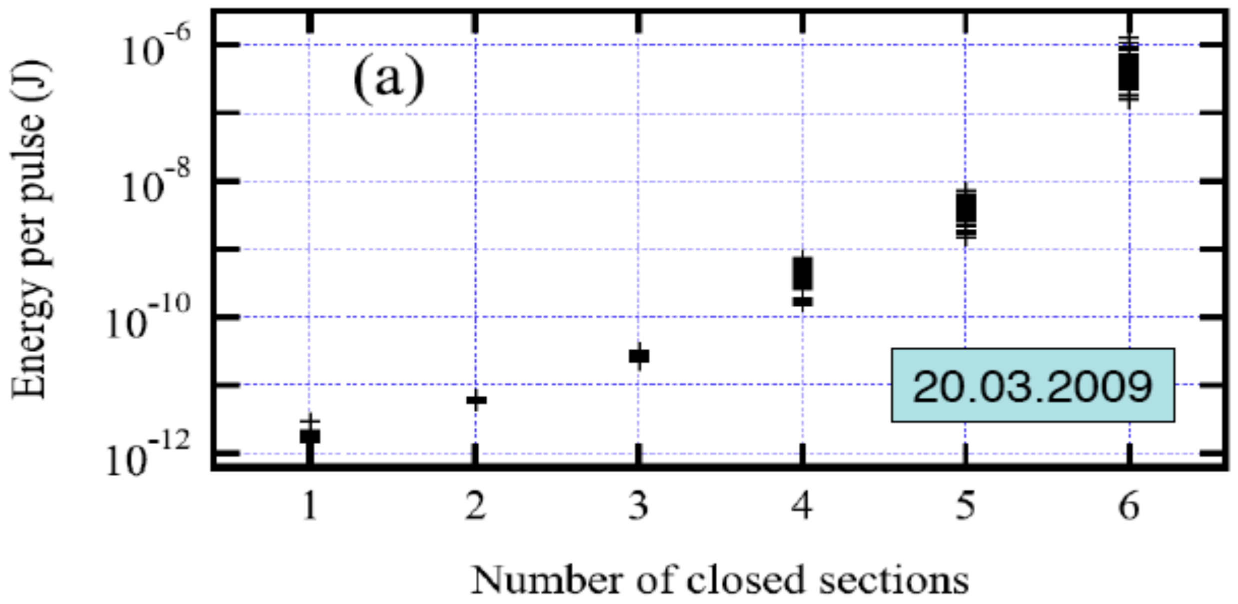



Single shot spectrum
spec105_1.txt
(a)
Intensity (a.u.)
Wavelength (nm)


Single shot spectrum
spec164_1.txt
(b)
Intensity (a.u.)
Wavelength (nm)


Single shot spectrum
spec216_1.txt
(c)
Intensity (a.u.)
Wavelength (nm)

Energy per pulse vs number of closed sections



Q=0.25 nC

Parameter	Unit	Value
Deflection paramter (K)	-	2.14
Period (λ_0)	mm	28
Number of periods per section	-	77
Number of section	-	6
Distance between sections	m	0.392
Natural focussing in x	-	-2.0×10^{-2}
Natural focussing in y	-	10.2×10^{-1}

Spectral width vs number of closed sections

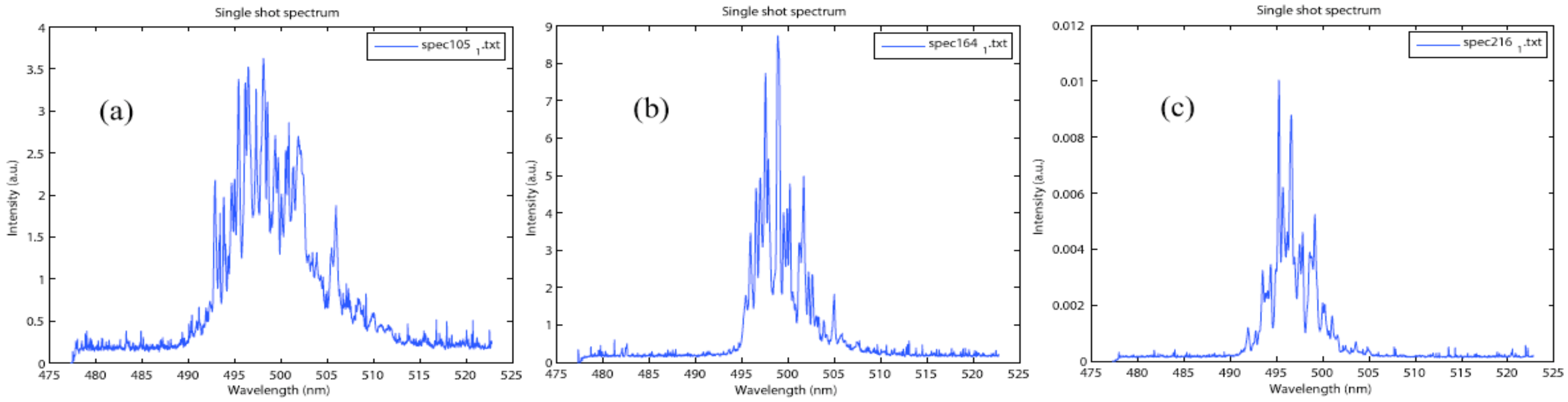
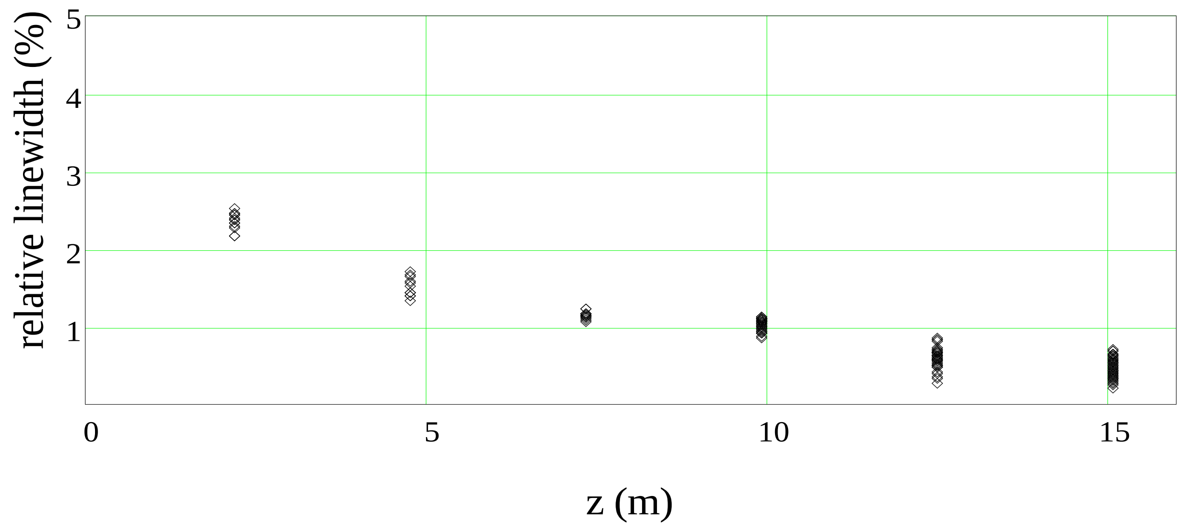
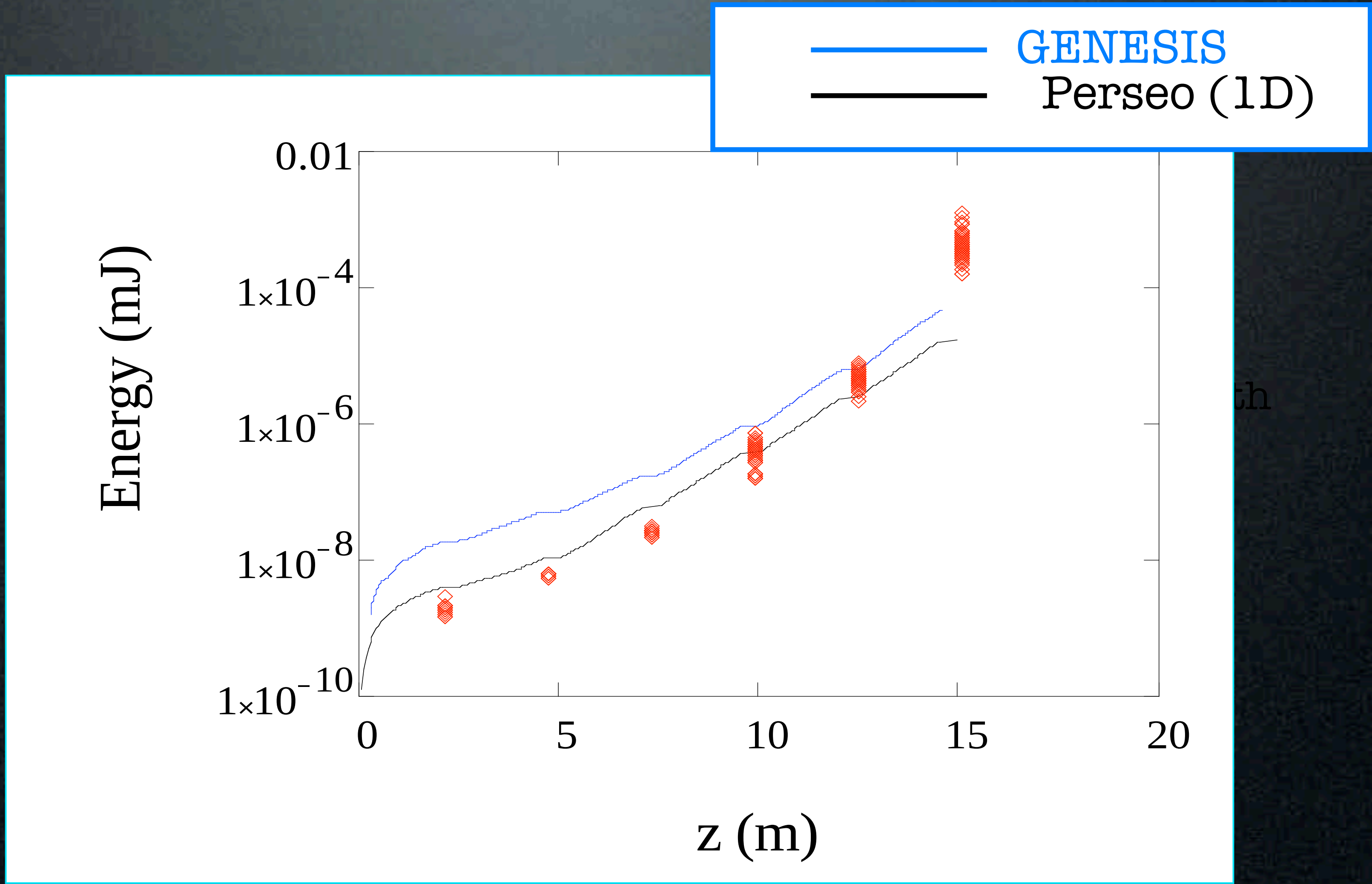


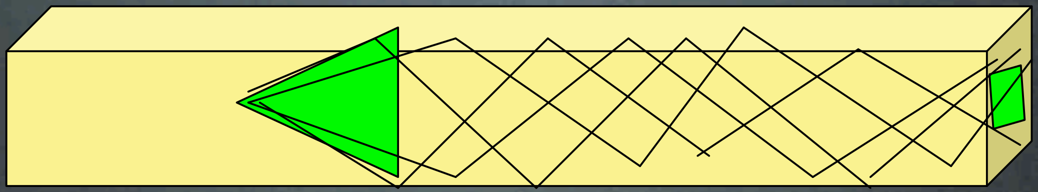
FIGURE 2: Undulator radiation spectra. Measurement with the high resolution spectrometer. (a) 4, (b) 5 and (c) 6 undulator sections closed. E=151-148 MeV, σ_γ=0.0001, Q=262 pC, σ_e=7 ps-fwhm, $\epsilon_{x,y}$=2.π.mm.mrad. (Measurement of the 09/03/20).



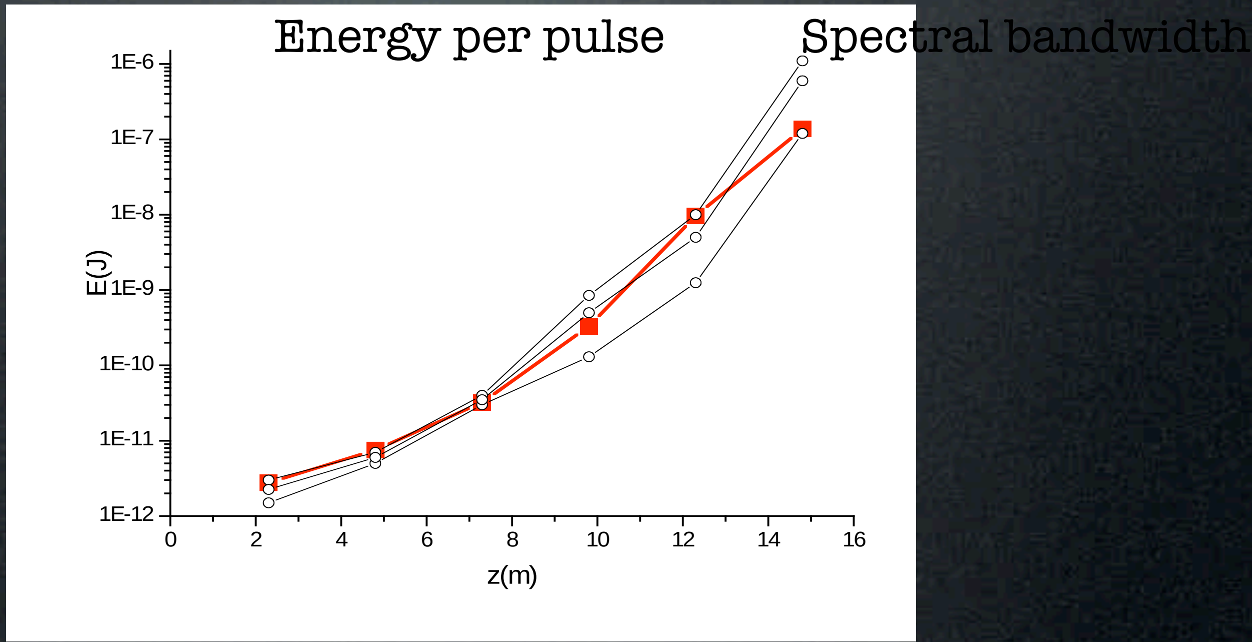
Preliminary data analysis



GENESIS simulations - Including radiation transport corrections

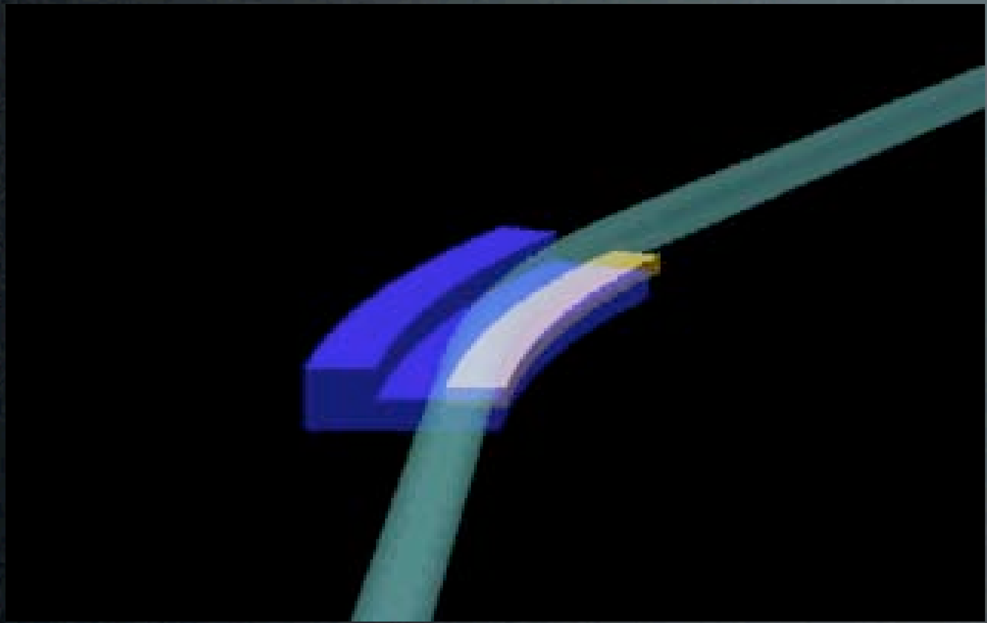


<div>=1 mr <div>=0.95 mr <div>=0.714 mr <div>=0.577mr <div>=0.5 mr <div>=0.446 mr

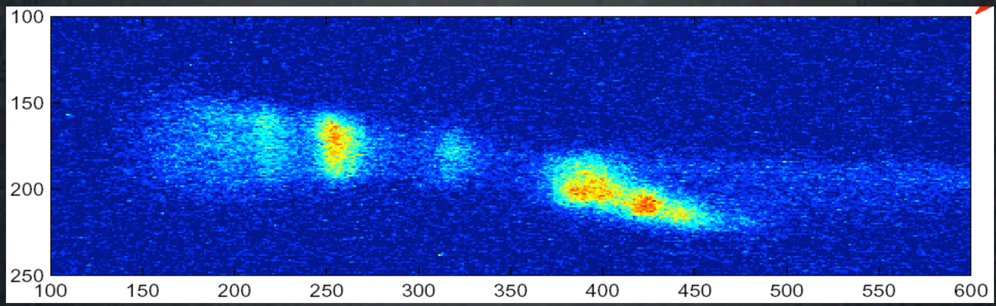


Velocity Bunching

Coherent Synchrotron Radiation in bending magnets

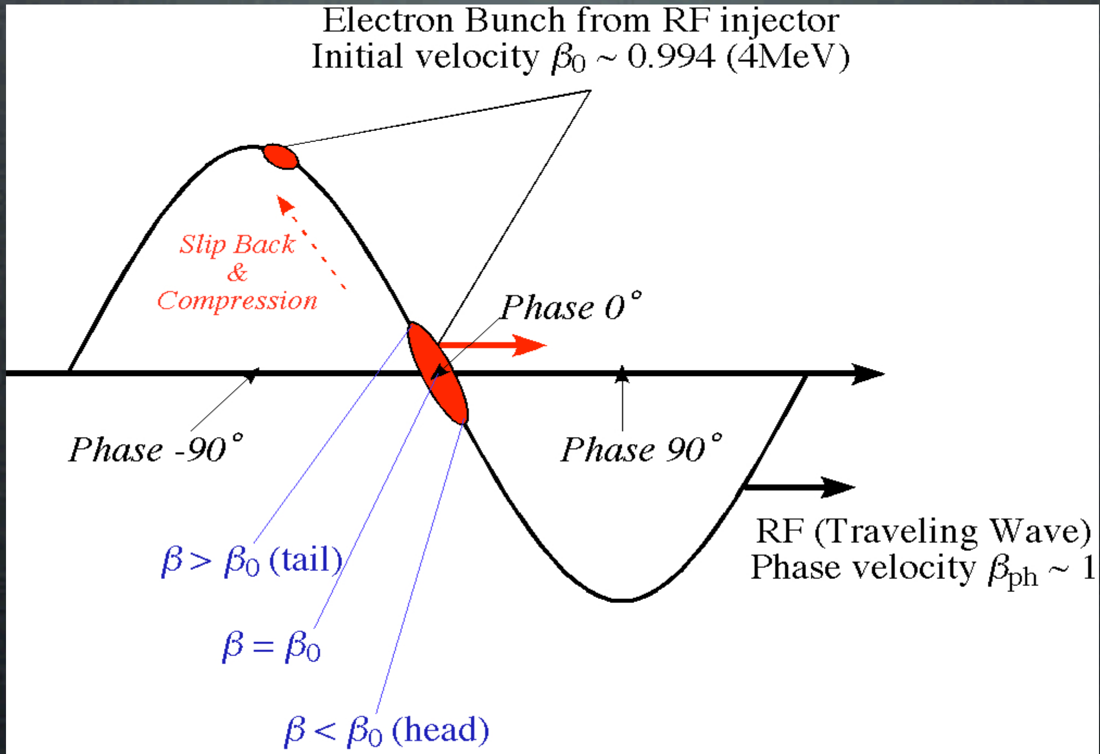


- **Powerful radiation generates energy spread in bends**
- **Energy spread breaks achromatic system**
- **Causes bend-plane emittance growth (DESY experience)**



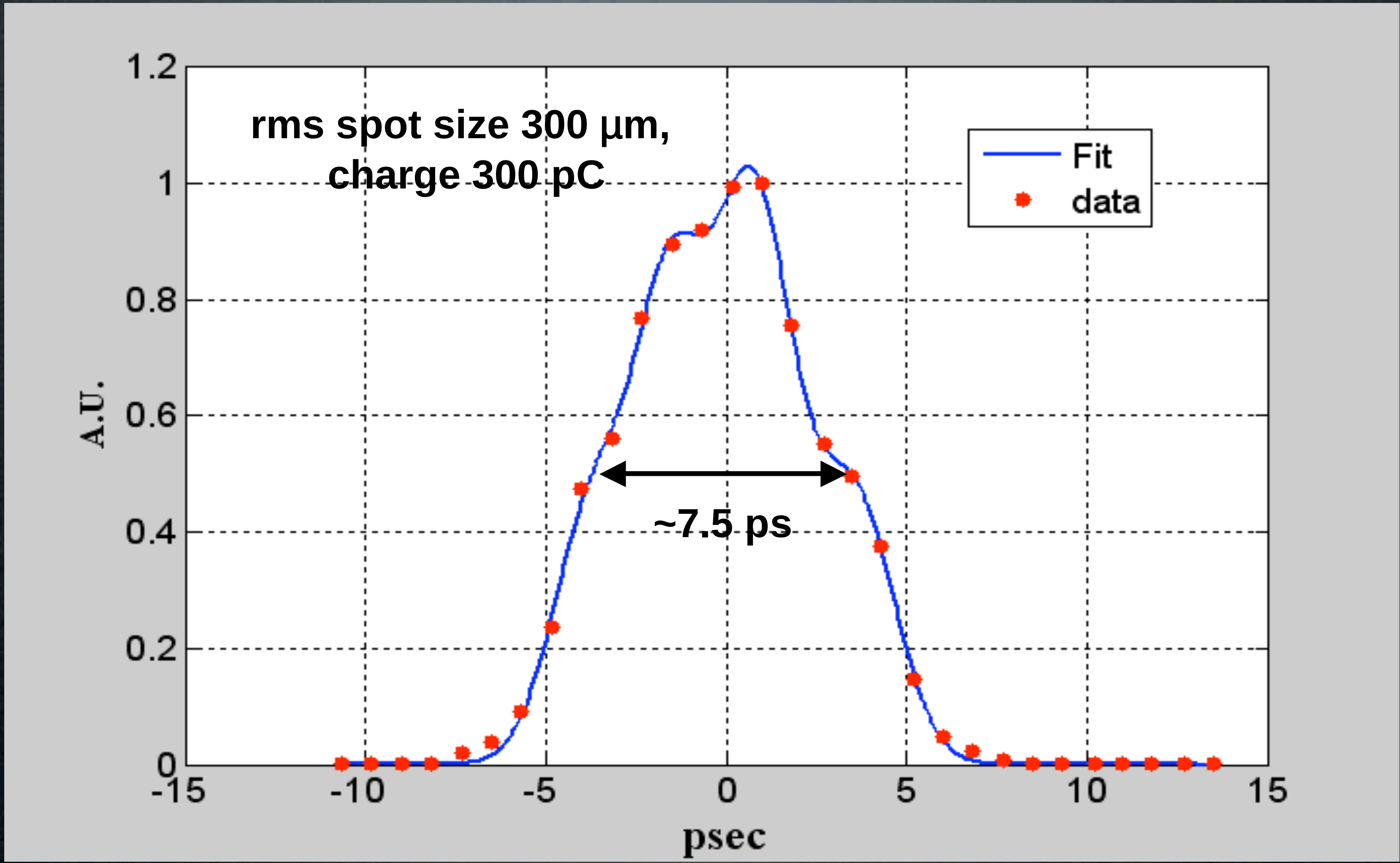
Velocity bunching concept

If the beam injected in a long accelerating structure at the crossing field phase and it is slightly slower than the phase velocity of the RF wave , it will slip back to phases where the field is accelerating, but at the same time it will be chirped and compressed.

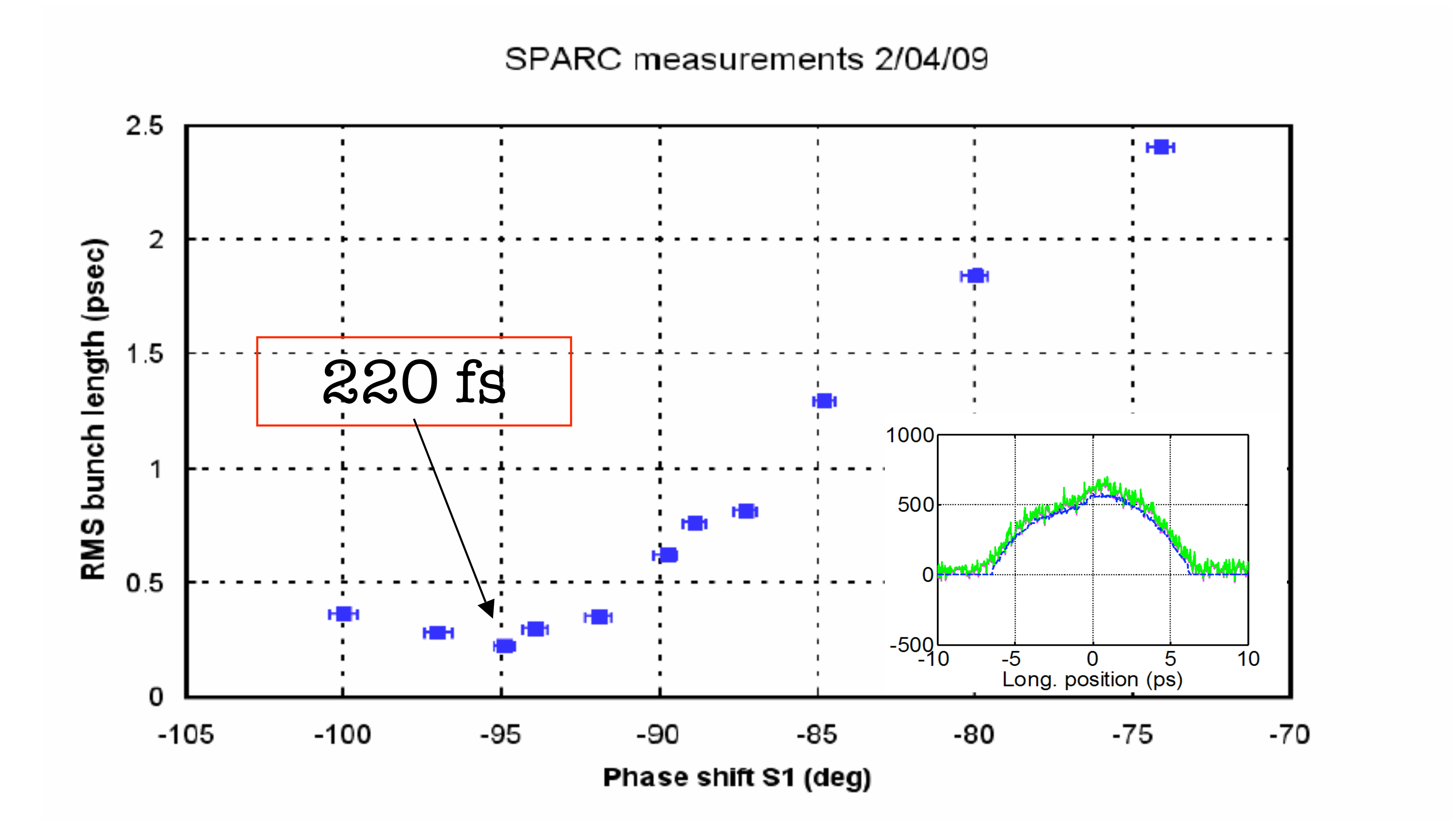


The key point is that compression and acceleration take place at the same time within the same linac section, actually the first section following the gun, that typically accelerates the beam, under these conditions, from a few MeV (> 4) up to 25-35 MeV.

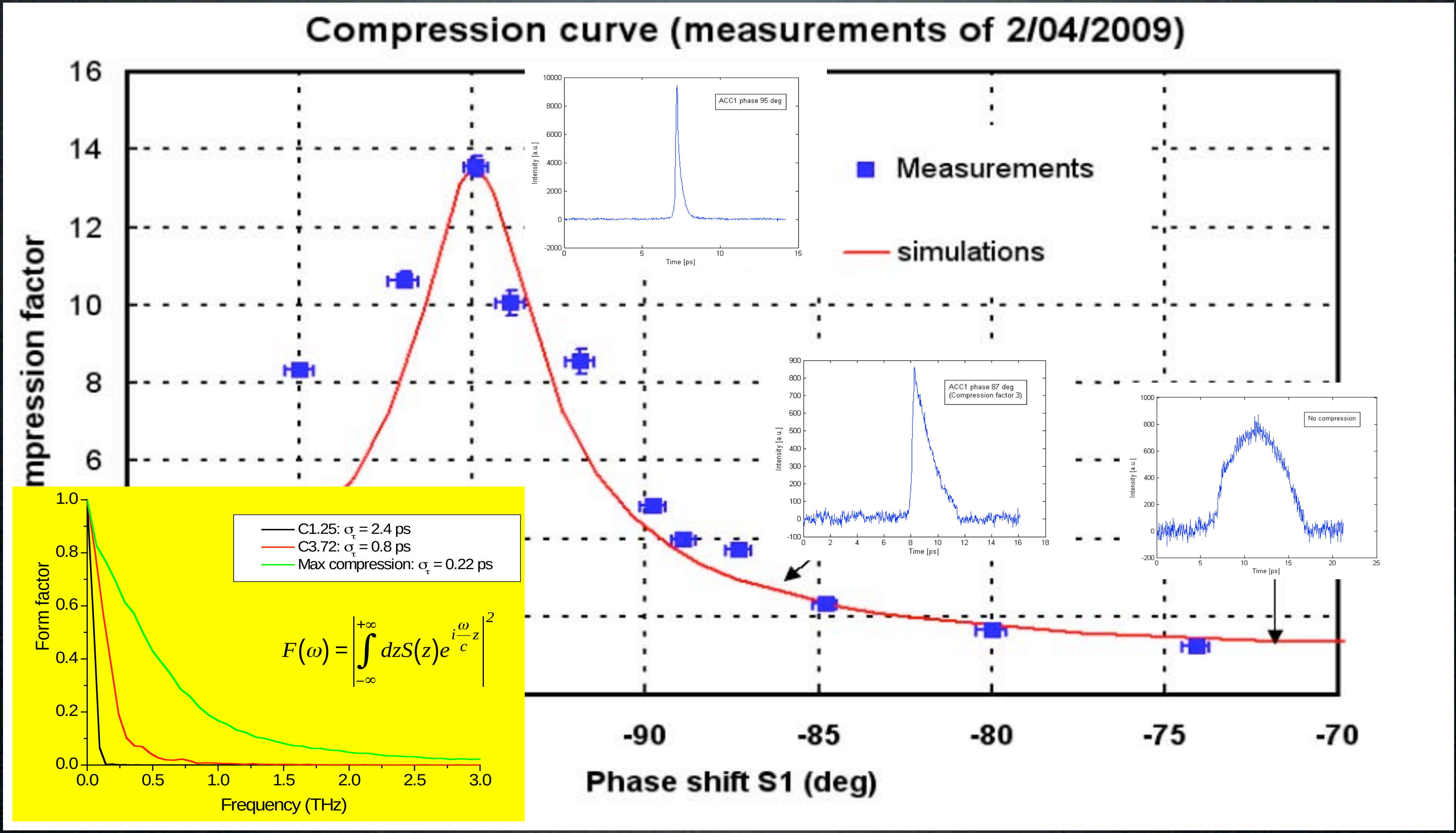
Laser temporal profile on cathode



Pulse length versus injection phase

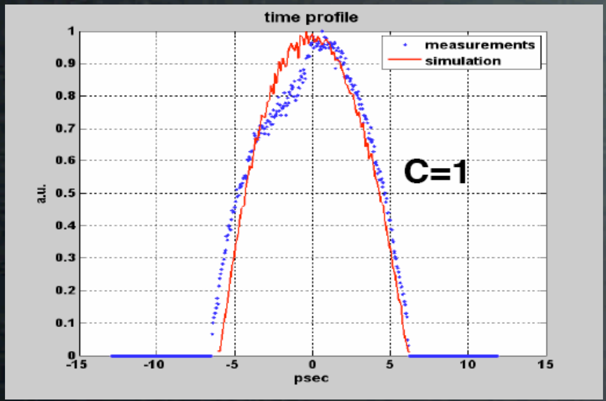


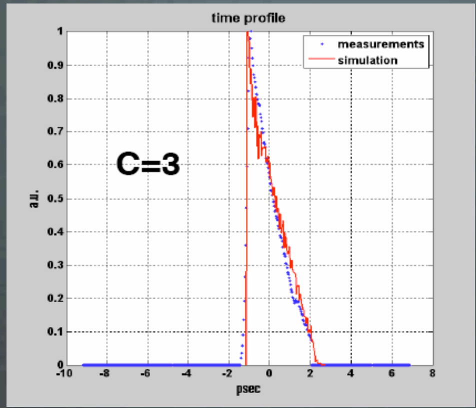
C-factor versus injection phase

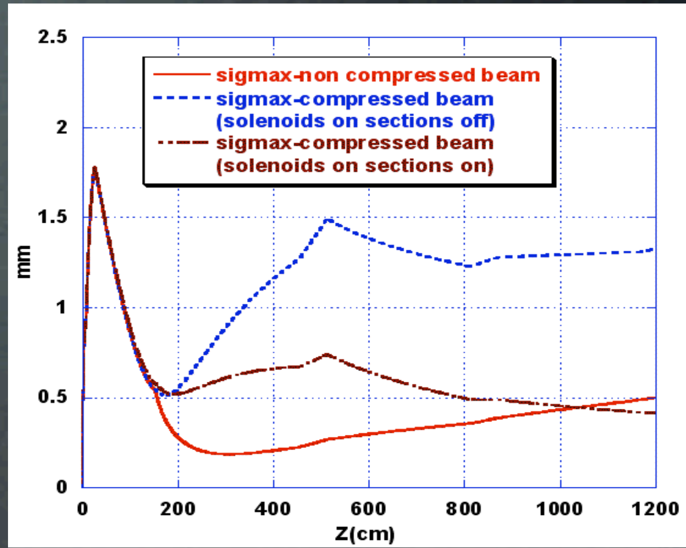


Emittance Compensation Study

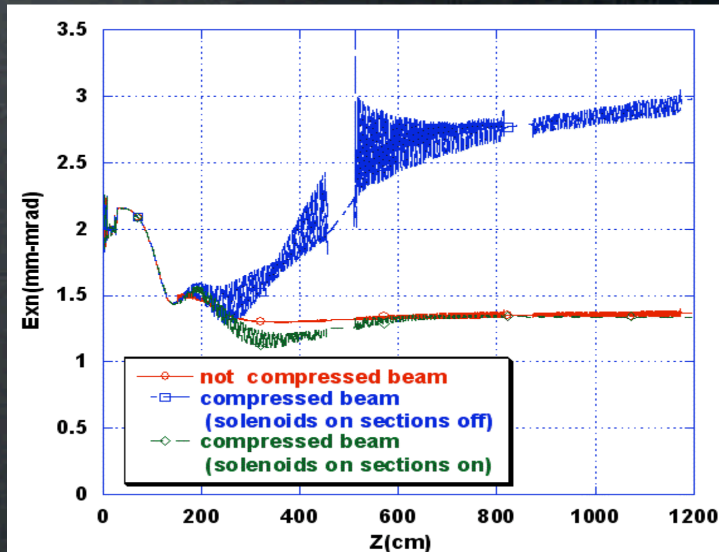
Measurement results with compression 3



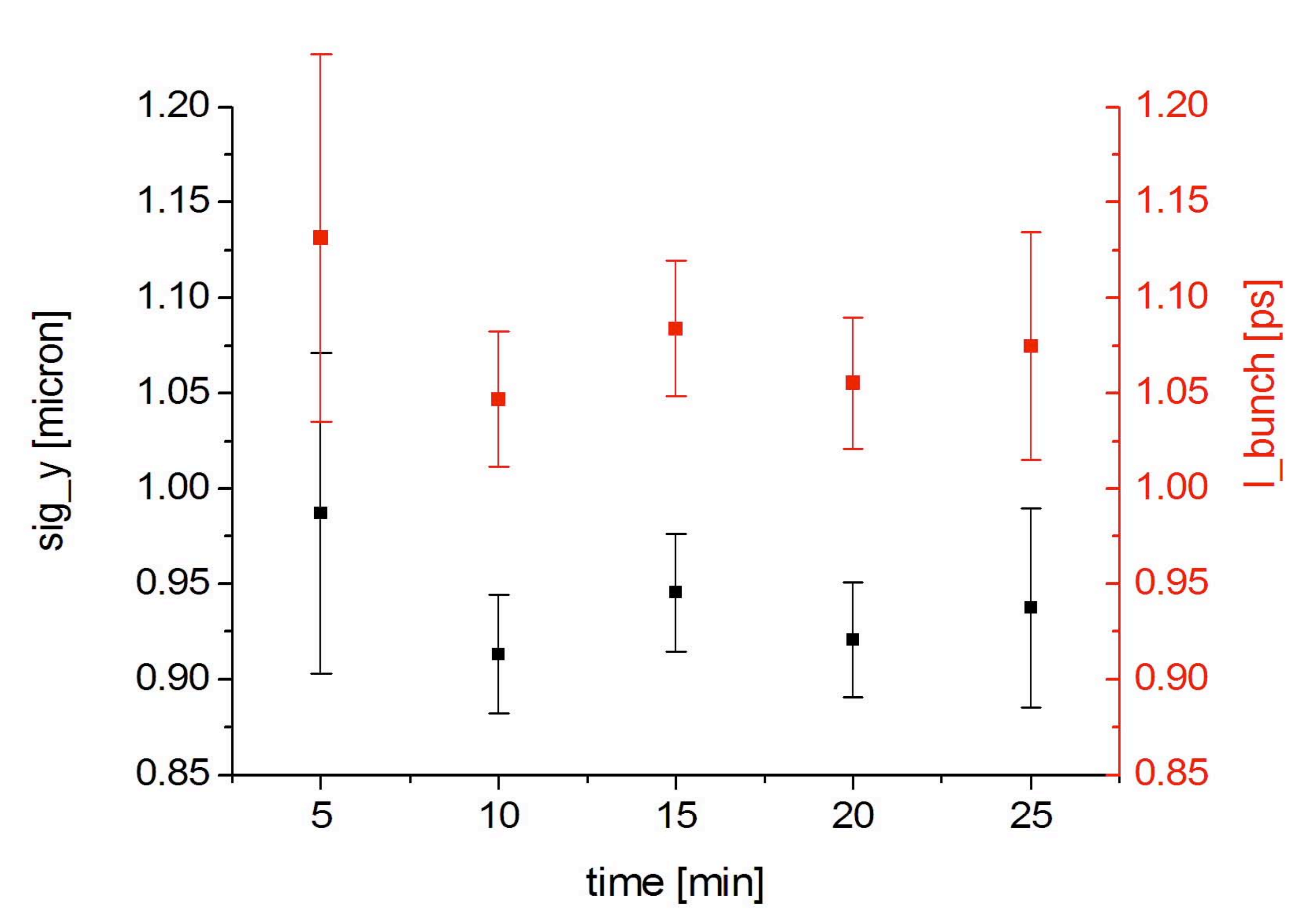




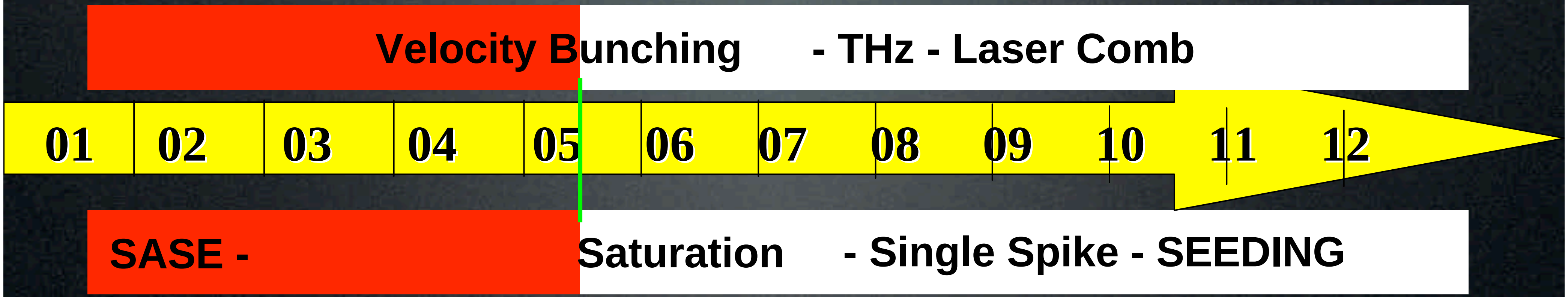
	No Compression	Compression 3
Bunch Charge	300 pC	300 pC
Injection phase	0 deg	-85 deg
Beam Energy	140 MeV	100 MeV
Total energy spread	0.11 %	1.0 %
Rms Bunch Length	3.25±0.16 ps	1.03±0.10 ps
Norm emittances x-plane	2.33 ±0.11 um	1.74±0.05 μm 4.33 ±0.83 μm solenoids off
Norm emittances y-plane	1.3 ±0.053 um	1.44 ±0.03 μm 6.06±0.40 μm solenoids off
Solenoid field	0 Gauss	400 Gauss



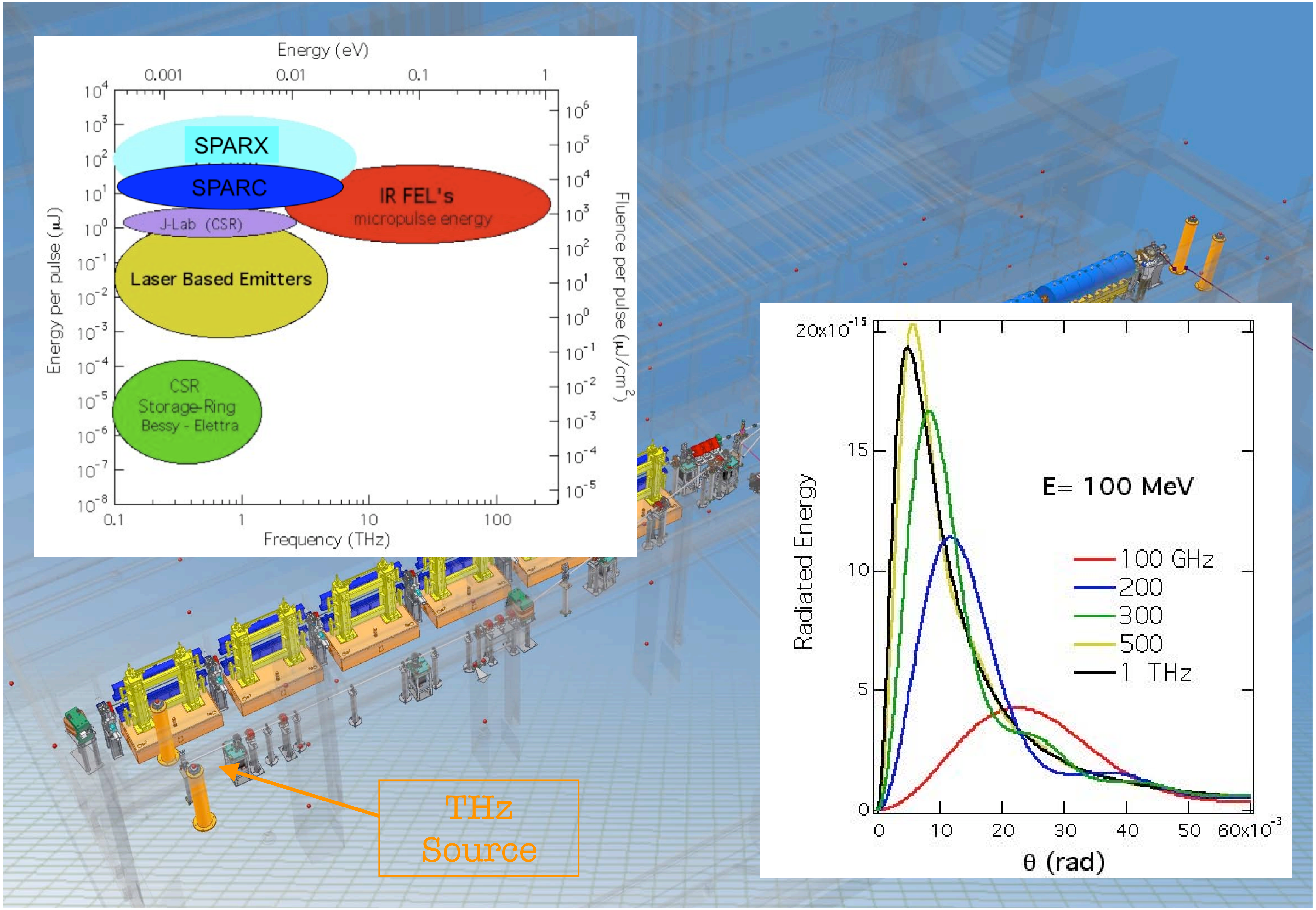
Long Term Stability



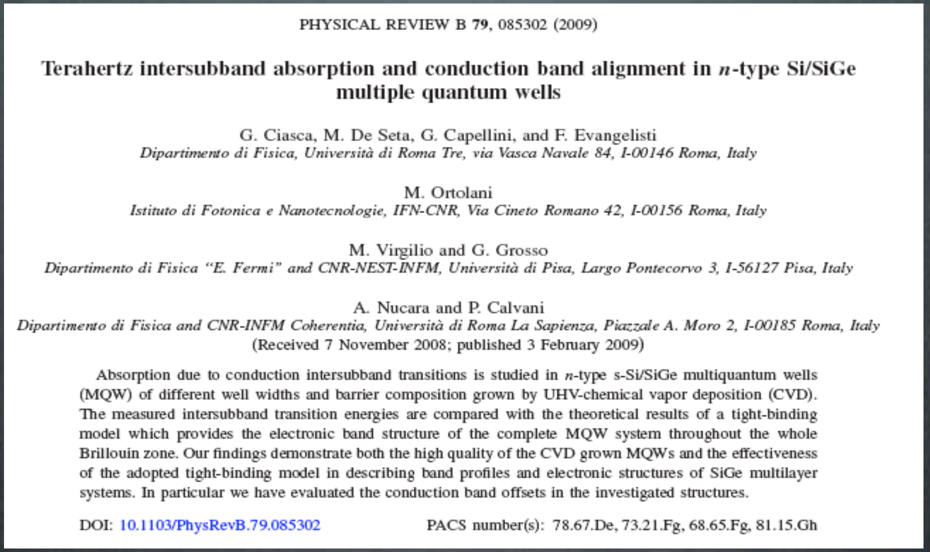
2009 planning



THZ @ SPARC


Energy (eV)
0.001
0.01
0.1
1
SPARX
SPARC
IR FEL's
micropulse energy
J-Lab (CSR)
Laser Based Emitters
CSR
Storage-Ring
Bessy - Elettra
Energy per pulse (μJ)
Fluence per pulse (μJ/cm2)
Frequency (THz)
0.1
1
10
100
Radiated Energy
E= 100 MeV
100 GHz
200
300
500
1 THz
θ (rad)
THz
Source

La collaborazione Sapienza-Roma3


PHYSICAL REVIEW B 79, 085302 (2009)

Terahertz intersubband absorption and conduction band alignment in *n*-type Si/SiGe multiple quantum wells

G. Ciasca, M. De Seta, G. Capellini, and F. Evangelisti
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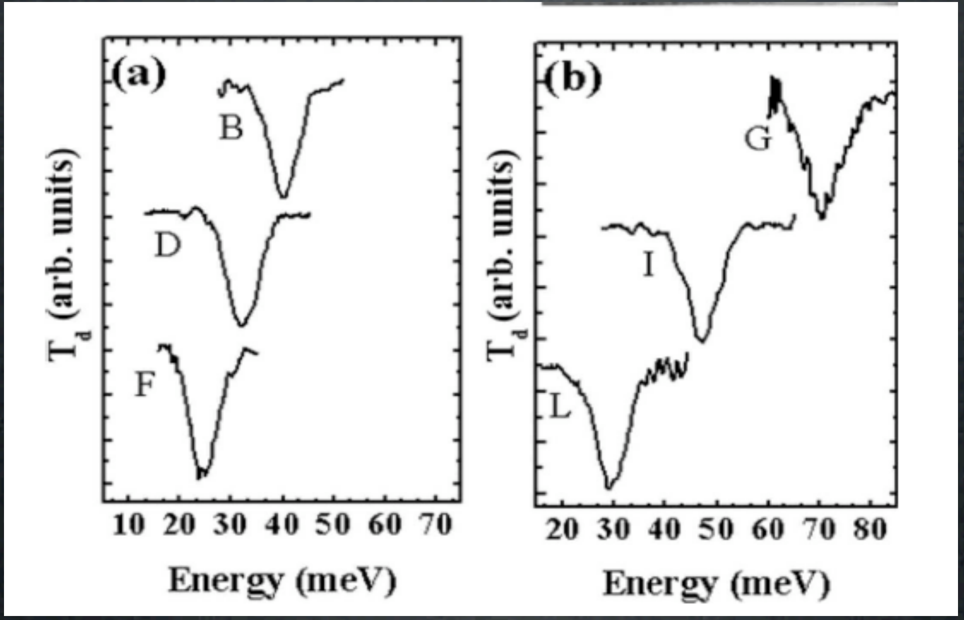
(Received 7 November 2008; published 3 February 2009)

Absorption due to conduction intersubband transitions is studied in *n*-type s-Si/SiGe multiquantum wells (MQW) of different well widths and barrier composition grown by UHV-chemical vapor deposition (CVD). The measured intersubband transition energies are compared with the theoretical results of a tight-binding model which provides the electronic band structure of the complete MQW system throughout the whole Brillouin zone. Our findings demonstrate both the high quality of the CVD grown MQWs and the effectiveness of the adopted tight-binding model in describing band profiles and electronic structures of SiGe multilayer systems. In particular we have evaluated the conduction band offsets in the investigated structures.

DOI: 10.1103/PhysRevB.79.085302 PACS number(s): 78.67.De, 73.21.Fg, 68.65.Fg, 81.15.Gh

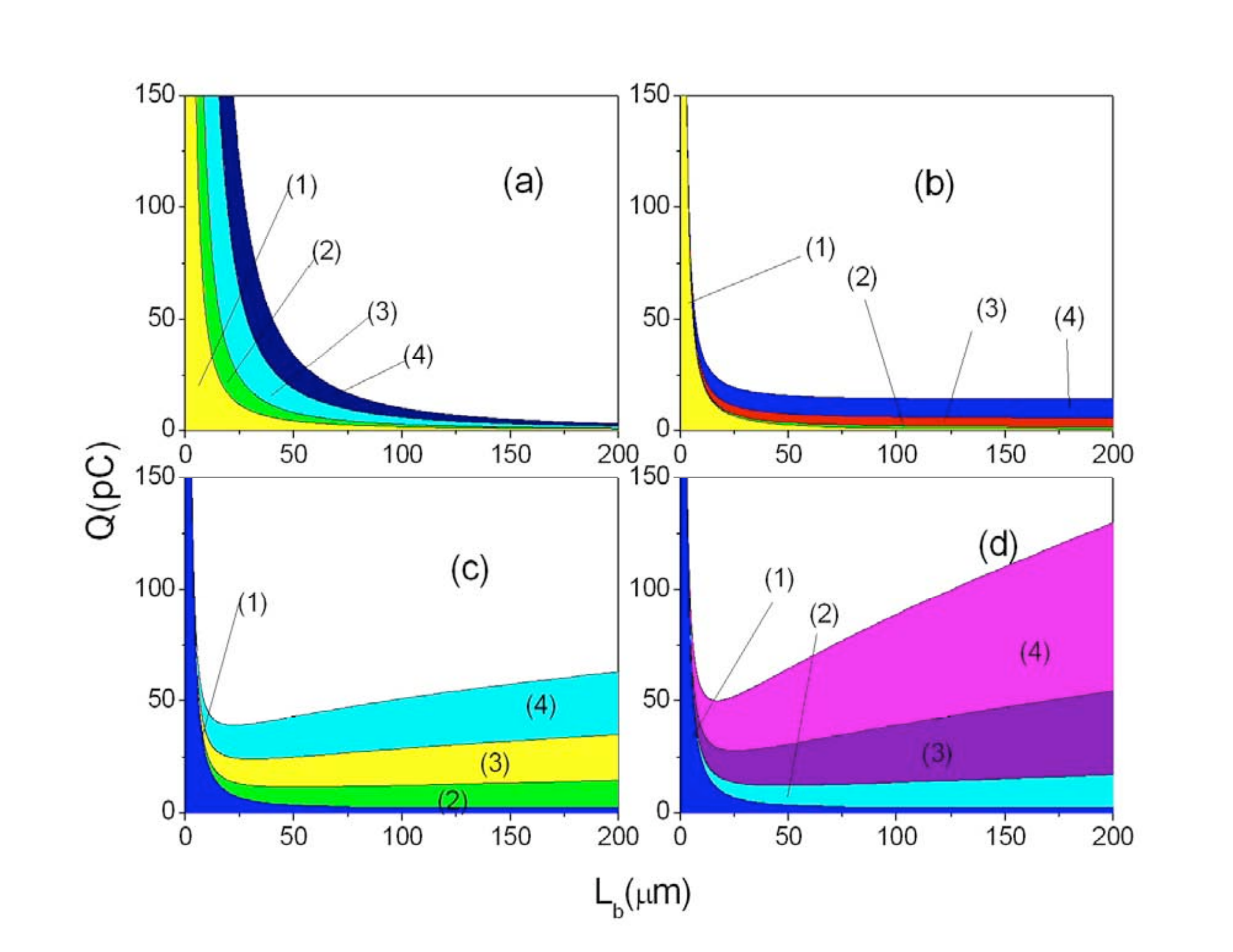


SASE Single Spike @ 700 nm

Single spike operation in SPARC SASE-FEL

M. Boscolo[a,*], M. Ferrario[a],
I. Boscolo[b], F. Castelli[b], S. Cialdi[b], V. Petrillo[b],
R. Bonifacio[c],
L. Palumbo[d]
L. Serafini[e]

$$Q = \left(\frac{\pi^2 I_A}{3\sqrt{3}c}\right)\left(\frac{\lambda_u(1+a_w^2)^3}{K_0^{\,2}[JJ]^2}\right)\left(\frac{\sigma_x^2}{L_b^2\gamma^3}\right)(1+\eta)^3$$



E(MeV)=121 MeV

γ=238

Q(pC)	C	I(A)	σ_z(μm)	ε_{nx} (μm)	ΔE/E (%)	$FWHM_{cath}$ (ps)	R(μm)
100	3	90	133	0.83	0.7	3.2	460
300	3.5	225	162	1.64	1	4.5	660
500	3.4	300	200	2.66	1.2	5.4	800

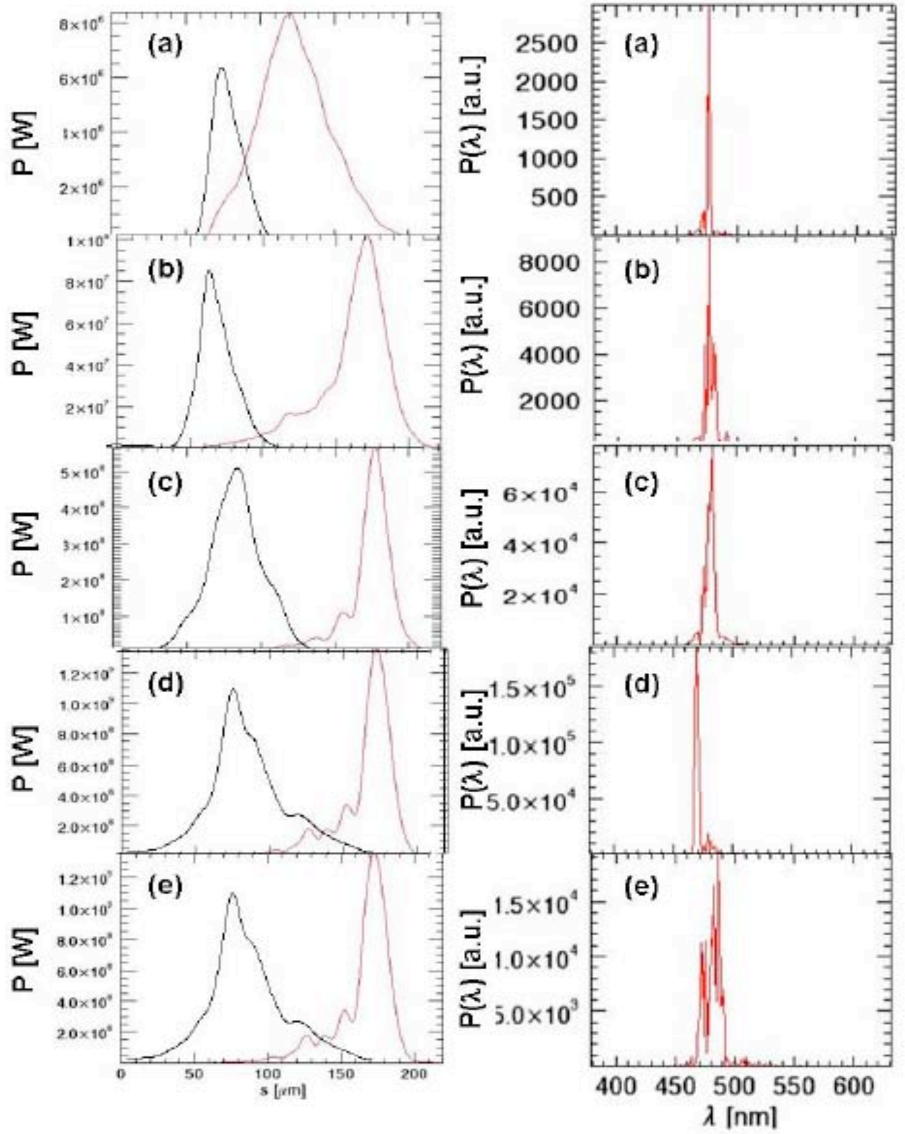


Fig. 7: Columns from left show, respectively, the power profile along the bunch coordinate s(μm) (in red) and superimposed in black the current profile and radiation spectrum at z_{max}. Rows from top are: (a) 25 pC, z_{max} =13 m, (b) 50 pC z_{max} =12 m, (c) 100 pC, z_{max} =11 m, (d) 300 pC, z_{max} =10 m, (e) 500 pC, z_{max} =9 m.

SPARC energy upgrade

Ti:Sa Regenerative amplifier

800 nm - 2.5 mJ – 1 kHz

+

High order harmonics

400 & 266 nm

+

High order armonics in gas:

266, 160, 114 nm

High Energy

Short duration

Spatial and temporal Coherence

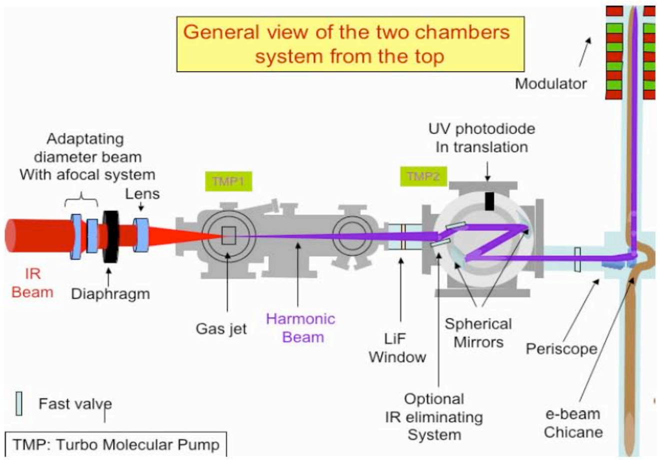
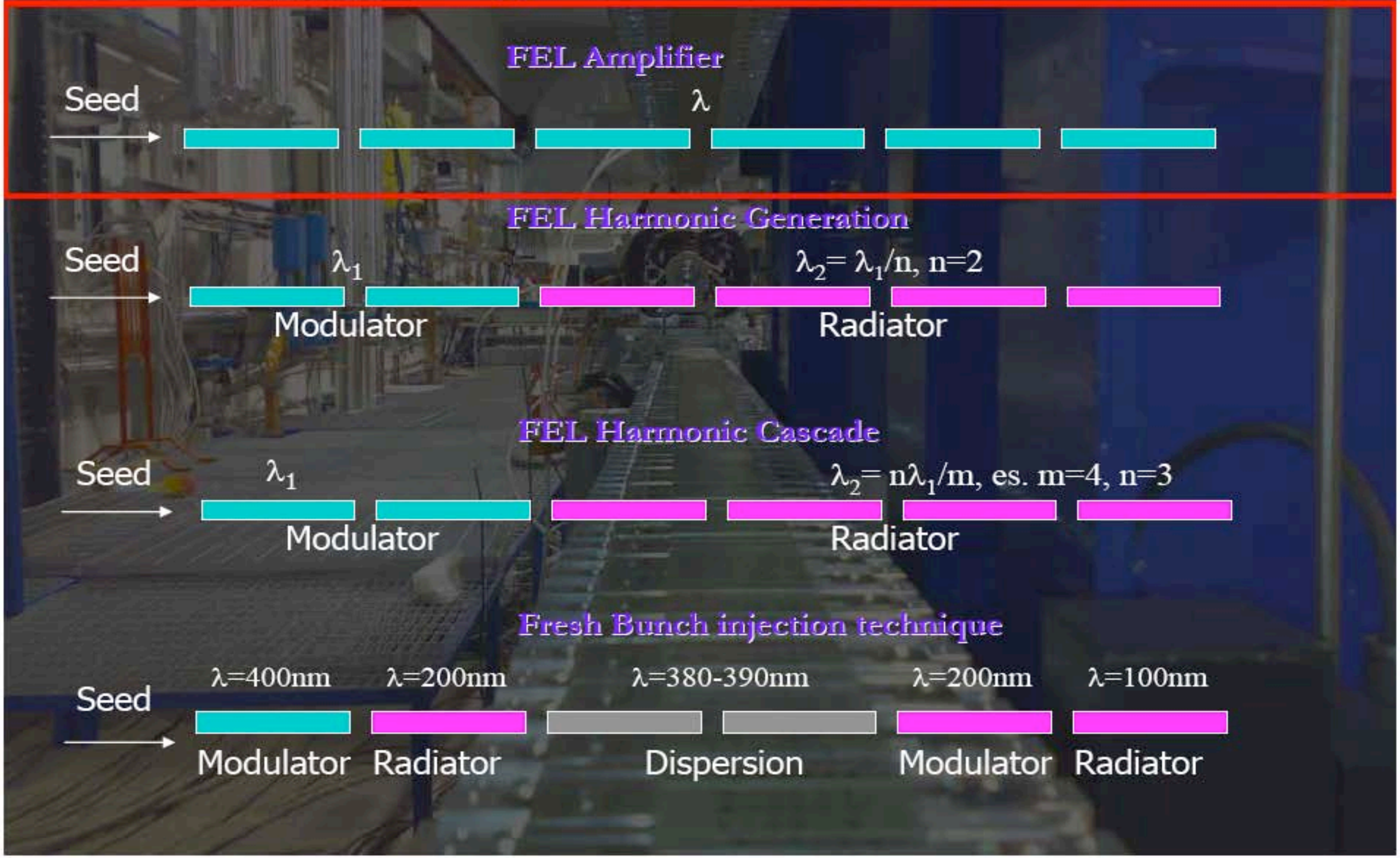


Fig. 31. *Lay-out of the harmonic chamber for the seeding experiment at SPARC. The first chamber is dedicated to the production of harmonics in gas. The second chamber is required for the opical mode adaptation.*

Seeded configurations



Laser Comb

Laser Comb: a giant microbunch instability

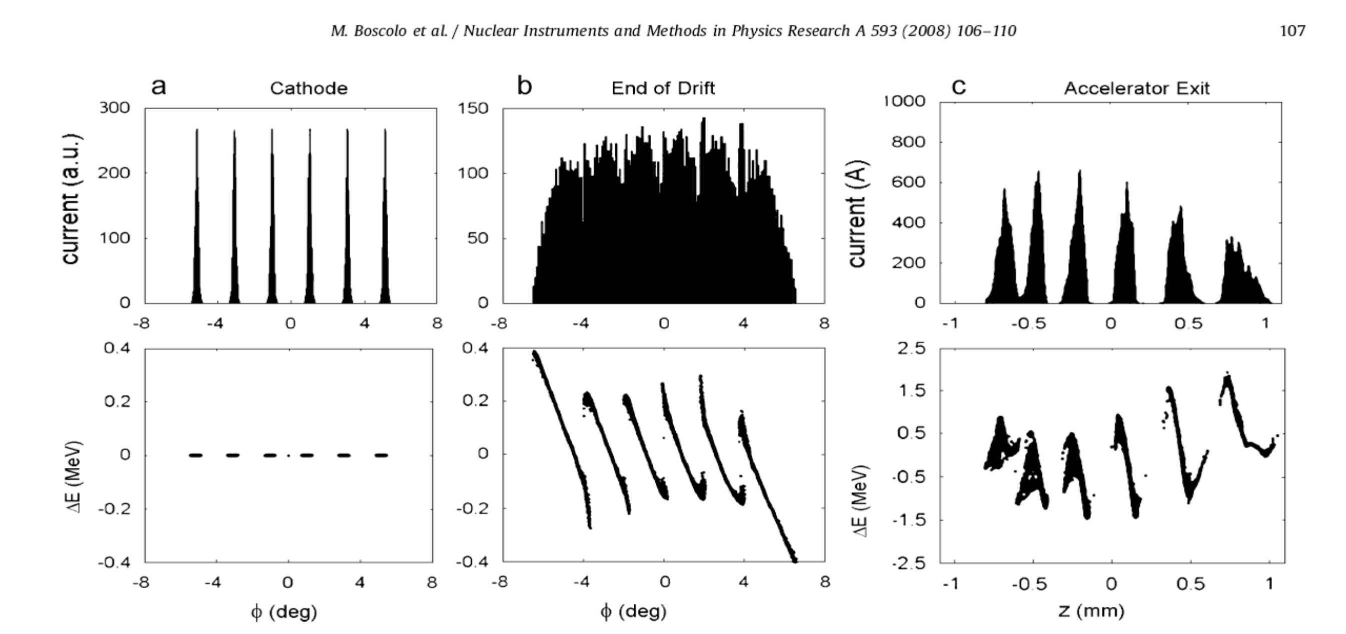
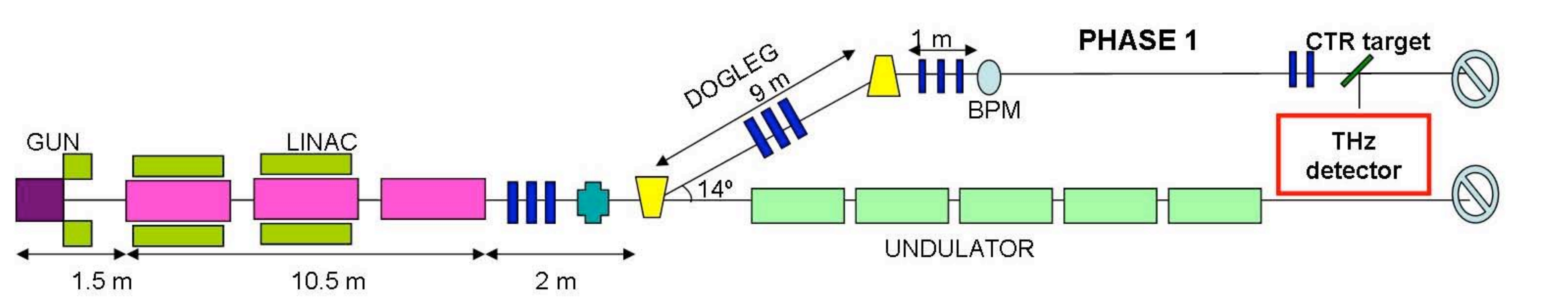
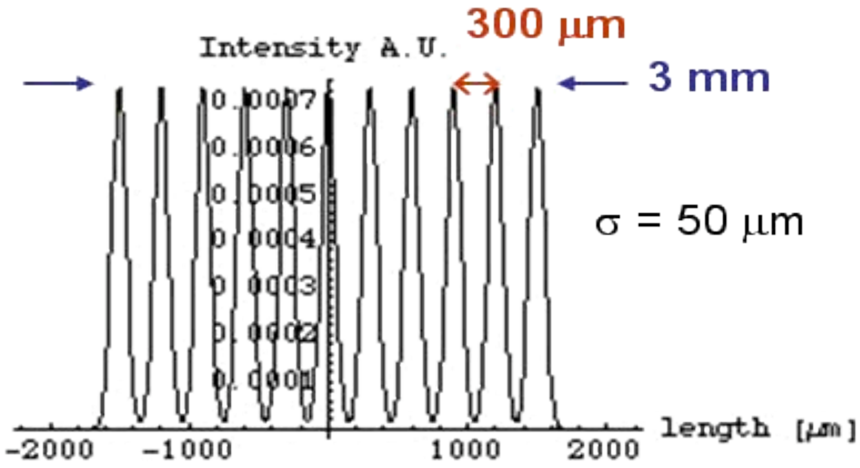
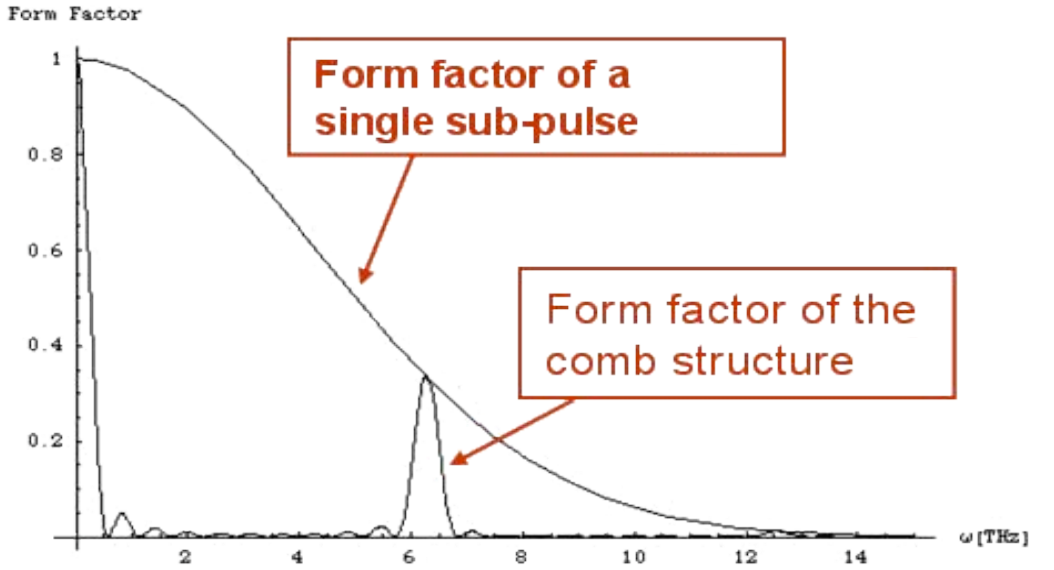


Fig. 1. Evolution of a six bunches electron beam train: the columns from left refer, respectively, to (a) the cathode, (b) the end of the drift at 150 cm and (c) the end of linac at 12 m far from cathode. The rows from top refer, respectively, to longitudinal profile and to energy modulation ΔE (MeV).



THz source





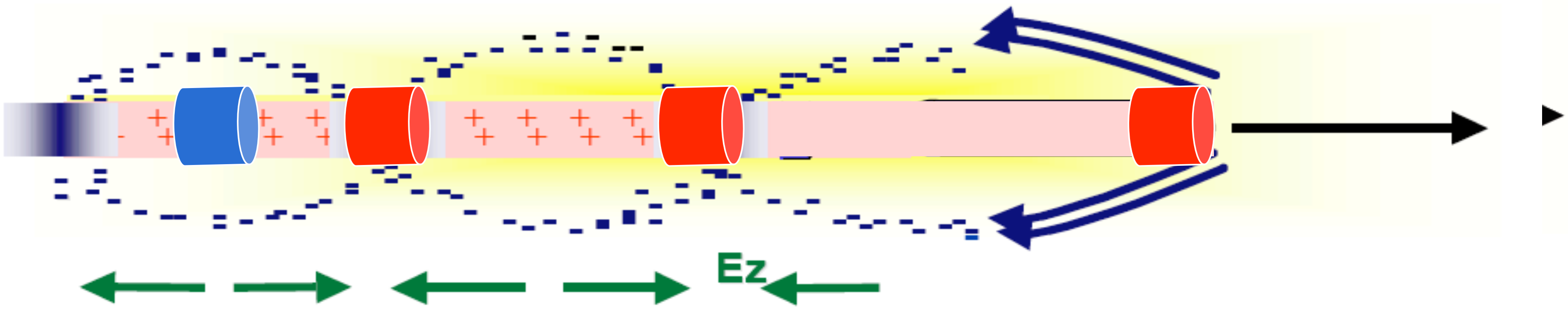
THz radiation can be easily produce by means of CTR

It is difficult to put high charge in sub-ps bunches

A laser comb structure in the longitudinal laser profile can solve this problem

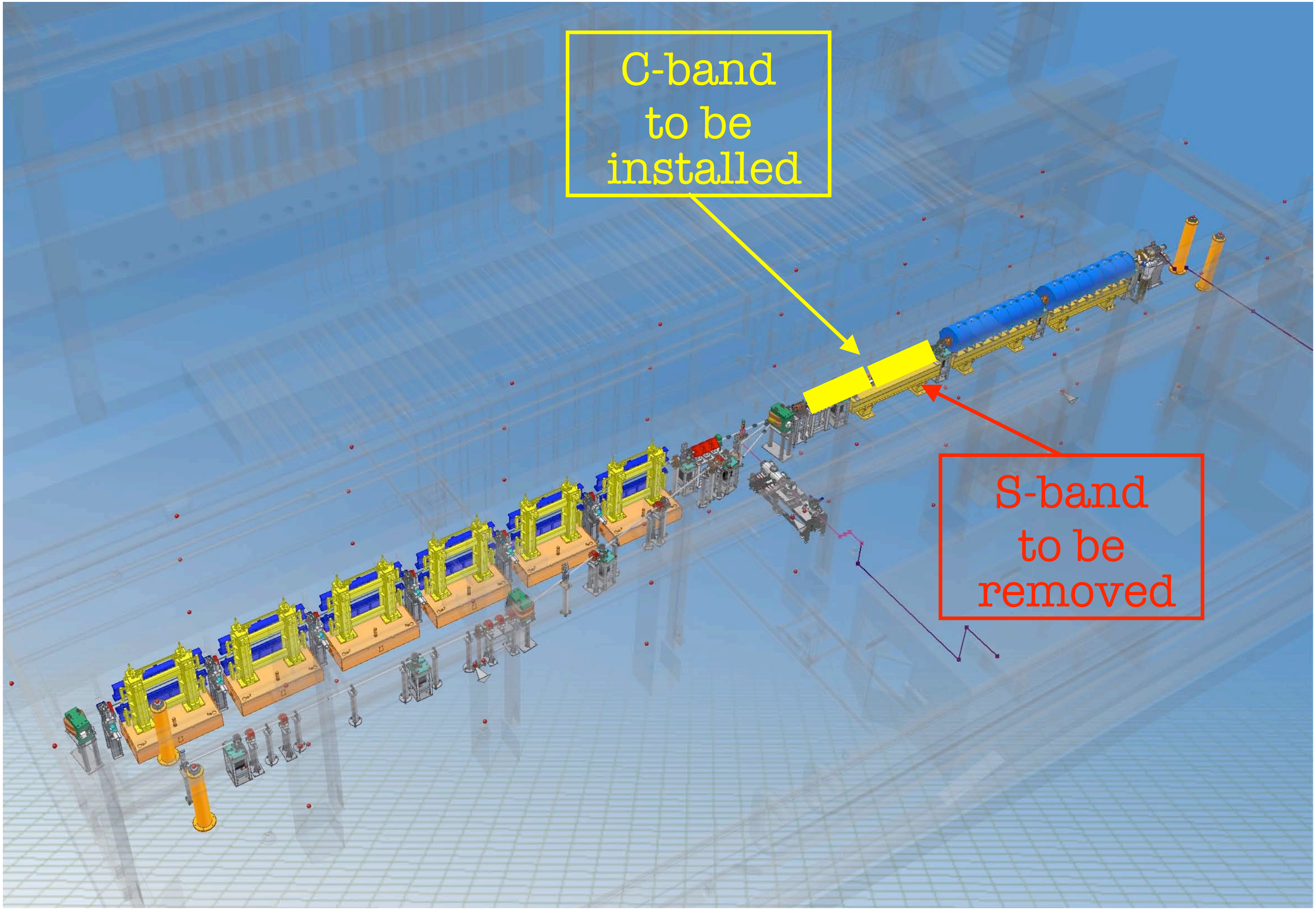
Plasma wakefield coherent excitation

- Space charge of drive beam displaces plasma electrons



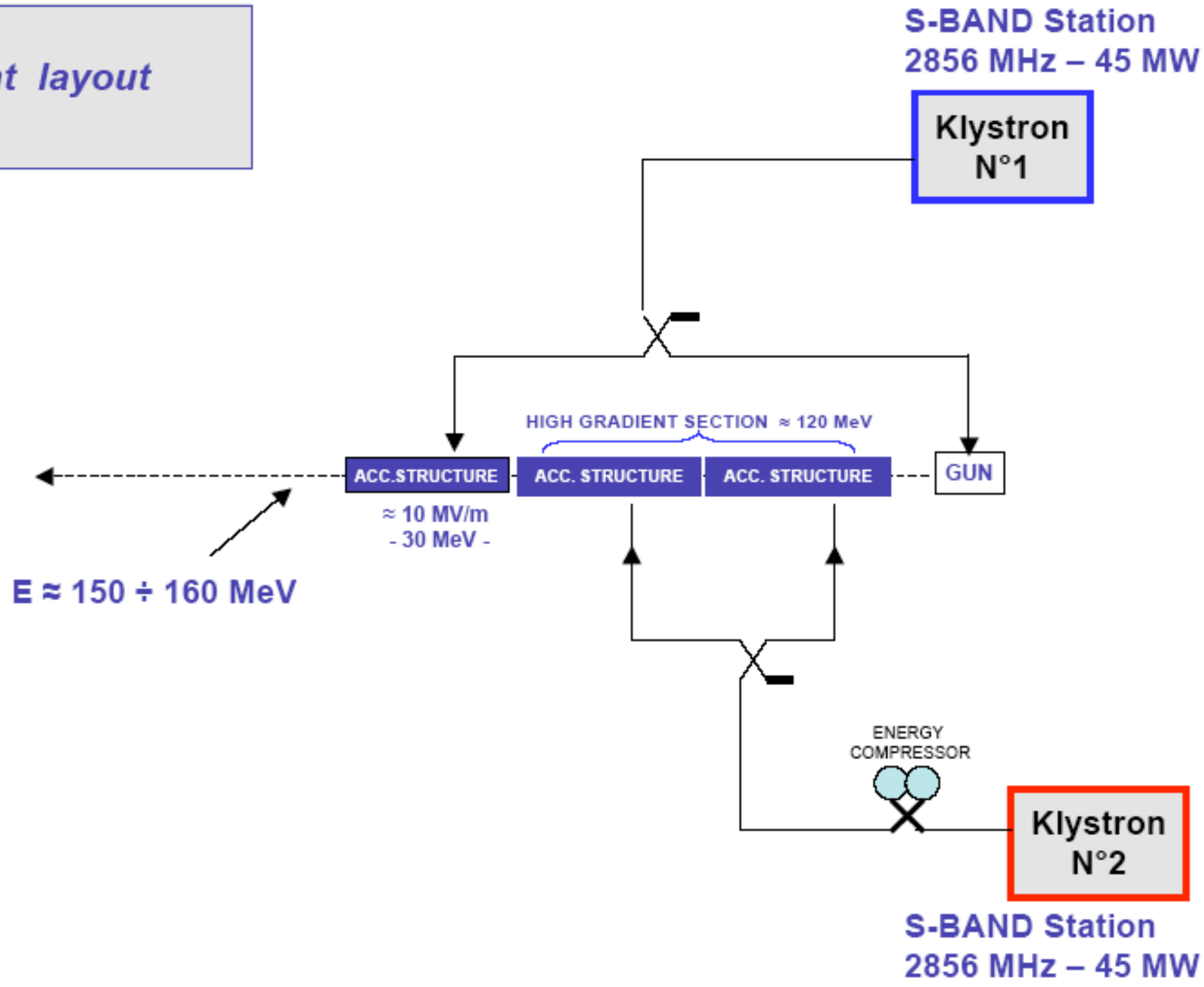
- Plasma ions exert restoring force => Space charge oscillations

SPARC energy upgrade

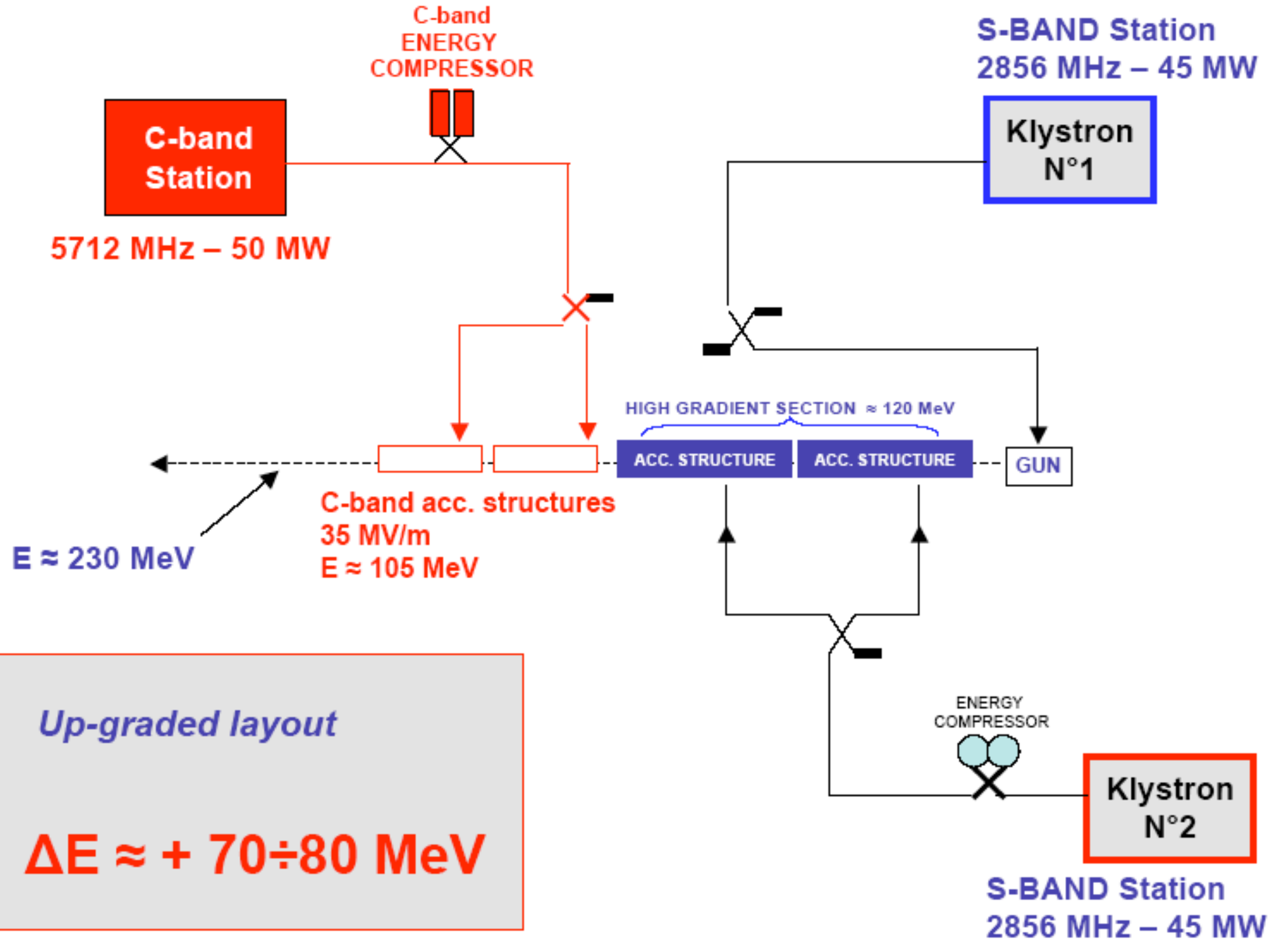

C-band
to be
installed
S-band
to be
removed

SPARC energy up-grading

Present layout



SPARC energy up-grading

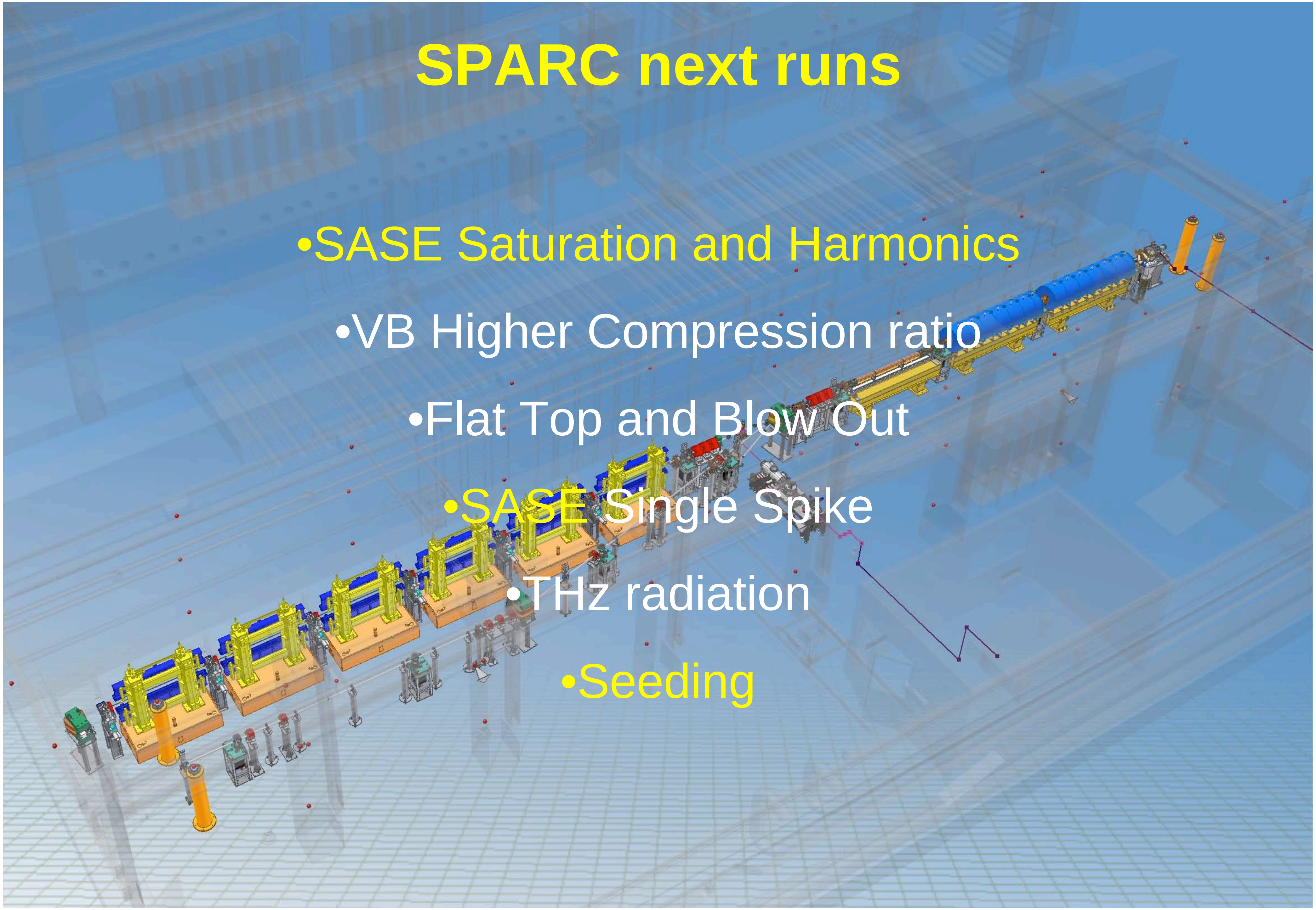


Up-graded layout

ΔE ≈ + 70÷80 MeV

Thank you

SPARC next runs



- SASE Saturation and Harmonics
- VB Higher Compression ratio
- Flat Top and Blow Out
- SASE Single Spike
- THz radiation
- Seeding